IRON AND STEEL ENGINEER

J. F. KELLY, Editor

CONTENTS

Volume II July, 1925 Number VII

Iron and Steel Exposition II

Editorials III

Application of Blast Furnace Gas and Air for Blowing a Gas Producer 269
By G. R. McDermott

Generation of Steam from Coke Breeze 274
By John Van Brunt

Coke Braize 276
By G. C. Emmons

Combustion Control by Machinery 286
By C. H. Smoot

Combustion Control 291
By T. A. Peebles

Automatic Combustion Control 293
By E. G. Bailey

Combustion Control 294
By G. S. Carrick

Insulation of Hot Surfaces and Furnace Walls 301
By L. B. McMillan

Items of Interest 312

(List of Advertisers—Page IV)

Copyright, 1925, by Association of Iron and Steel Electrical Engineers.

Published Monthly by

Association of Iron and Steel Electrical Engineers

706 Empire Building, Pittsburgh, Pa.

Entered as second-class mail matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879.

Subscription Price $5.00 per Year. Single Copy 50c.

Iron and Steel Exposition
September 14th to 19th, 1925

Philadelphia
Commercial
Museum

120,000 Square Feet

Reservations Being Made

Address

Iron & Steel Exposition

706 Empire Building - Pittsburgh, Pa.

EDITORIAL

TO THE MEMBERSHIP OF THE ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS

Pittsburgh, July 20, 1925.

Through your medium, The Iron and Steel Engineer, I am calling your attention to the Twentieth Annual Convention of your Society, the Association of Iron and Steel Electrical Engineers.

Less than sixty days remain until we are in session at the Commercial Museum in the City of Philadelphia, Pa. You realize, therefore, that you should arrange your plans just as early as you possibly can in order that you will be in attendance at what is believed to be one of the largest conventions that the Association has been permitted to enjoy since its inception.

The Technical sessions, which are under the direct supervision of the Papers Committee, Mr. C. S. Proudfoot, of the Bethlehem Steel Company, chairman, are without exception, the best that has ever been offered to you. THE SELECTION AND MAINTENANCE OF OIL CIRCUIT BREAKERS is a subject which all Electrical Engineers and Superintendents in the steel industry are interested in. A new development in the Electrical art is to be brought before you in a paper covering the subject of FROG LEG ARMATURE WINDINGS. Every Engineer or Superintendent who has to do with direct current motors cannot afford to miss this meeting. Another subject which is of vital interest to the entire Steel Industry is THE APPLICATION OF ELECTRICITY FOR HEATING PURPOSES. A report will be furnished you, showing how it is possible, with the application of electricity for heating purposes to take the ingot all the way down to the finished material. In connection with this report, the Donner Steel Company has consented to furnish a report covering the ELETRICALLY HEATED SOAKING PIT, which is in operation at their plant. The subject of PREHEATED AIR is receiving a great deal of attention in the Steel Industry at the present time and a paper will be presented covering BOILER OPERATION BY THE USE OF PREHEATED AIR FOR COMBUSTION. How often does the question arise: Shall Our Auxiliaries in Our Power Houses Be Electrically or Steam Driven? This subject will be answered to everybody's satisfaction in a paper, AUXILIARIES AND AUXILIARY DRIVES FOR STEAM ELECTRIC GENERATING STATIONS.

Your Iron and Steel Exposition, as in the past, will be a practical demonstration of the developments in the Electrical, Mechanical and Combustion Arts. This feature alone should interest the Executives, the Engineers and the Superintendents in the Iron and Steel Industry, as it really is the only time during the year that you are able to see the particular type of apparatus which is offered for your personal examination and criticism.

The Executives, as well as the President of your Society, earnestly invite your serious and active co-operation in all the undertakings and activities of the Twentieth Annual Convention, being held at Philadelphia, September 14th-19th, 1925.

Yours very truly,

A. C. CUMMINS, President.

INDEX TO ADVERTISERS

A

Alliance Machine Company 351
Allis Chalmers Mfg. Company 342
American Heat Economy Bureau Cover 1
Appleton Electric Company 346

B

Baker R. & L. Company 349
Benjamin Electric Mfg. Company 329
Bussmann Manufacturing Company 327

C

Cleveland Crane & Engineering Company 338
Crocker Wheeler Company 355
Corliss Carbon Company 350
Crouse Hinds Company 331
Cutler Hammer Mfg. Company 339
Cutter Electrical & Mfg. Co. 325—Cover 3

D

De Laval Steam Turbine Company 314
Delta Star Electric Company 337
M. H. Detrick Company 359
Doubleday Hill Electric Company 350-354
Duquesne Light Company 317

E

Economy Fuse & Mfg. Company 322
Electric Controller & Mfg. Company 333

F

The Fafnir Bearing Company 318
Farrel Foundry & Machine Company 340
Fawcus Machine Company 348

G

General Electric Company Cover 4

H

Harnischfeger Corporation 358
Hyatt Roller Bearing Company 316

I

Iron City Electric Company 356

J

W. J. Jeandron 341
Johns Manville, Inc. 323

K

Keystone Lubricating Company 324

L

George T. Ladd Company 362
Le Carbone Brush Company 341

M

Martindale Electric Company 352
Moloney Electric Company 353
Monitor Controller Company 344
Morgan Construction Company 357
Morgan Engineering Company 363
Morganite Brush Company 357

N

National Carbon Company 315
Nichols Lintern Company 345
Norma Hoffmann Bearing Corp. 335
R. D. Nuttall Company 334

O

Ohio Electric & Controller Co. 360

P

Packard Electric Company 364
Pittsburgh Transformer Company 349
Pawling & Harnischfeger Corp. 358
Pyle National Company 361

R

Reliance Electric & Engineering Company 321
Roller Smith Company 351
Rollway Bearing Company 320
Rowan Controller Company 347
Rumsey Electric Company 348

S

Shepard Electric Crane & Hoist Co. 319
SKF Industries, Inc. 326
Smith & Serrell 356
Stackpole Carbon Company 328
Standard Underground Cable Co. 352
Strom Ball Bearing Mfg. Co. 330

T

Thomas Flexible Coupling Company 336
Thompson Electric Company 347
Timken Roller Bearing Company 343
Tool Steel Gear & Pinion Company 354
Trumbull Electric Mfg. Co. 355

U

United States Graphite Company 353

V

V. V. Fittings Company 332

W

Westinghouse Electric & Mfg. Co. Cover 2

Y

York Insulated Wire Works of G. E. Co. 346

The Application of Blast Furnace Gas and Air for Blowing a Gas Producer*

By G. R. McDERMOTT†

THE standard method in use at present for blowing gas producers, in the steel plant, is either by a steam turbine driven centrifugal blower or by a syphonic steam jet.

The chemical reactions taking place in a gas producer are comparatively simple. At the junction of the ash and coke beds, the coke actually burns by combining with the oxygen of the air delivered by the blower and the burning gives off a large amount of heat with the production of carbon-dioxide, CO_2. The heat is utilized to heat the coal above, forming a bed of incandescent coke or carbon, carbon-dioxide. CO_2, in passing up through the bed of hot coke is reduced to carbon-monoxide, CO. This reaction is endo-thermic, in that it requires heat. If a producer could be run by air alone, it would be ideal, but the heat generated by the combustion would melt the ashes produced, causing the formation of clinkers. Ash from a good coal should not fuse below 2200° to 2500° F., hence the temperature of the combustion zone should be slightly lower.

To prevent clinkering, the excess heat must be removed and the temperature of the combustion zone must be maintained below that of the melting point of the ash. This is accomplished by the addition of steam to the air, which in the case of the steam turbine driven blower is the exhaust from the turbine, while with the jet type of blower the steam is used directly for drawing in the air and in doing so they are both mixed directly.

At the Illinois Steel Company's Works at South Chicago, we were presented with the problem of the utilization of excess blast furnace gas other than that required for the production of electric and steam power. As a result we are operating six regenerative slab heating furnaces for the plate mills and at times blast furnace gas is used as fuel for open hearth furnaces. In both applications the blast furnace gas is mixed with producer gas before they pass through the regenerators of the furnaces. In the case of the slab heating furnaces, the percentage of the total heat units supplied to the heating furnaces averages 55% over a month's period; however, when charging hot steel the percentage will at times be 75%.

Still having an excess amount of blast furnace gas, the possibility of using blast furnace gas as a cooling agent in place of steam for blowing gas producers suggested itself. This gas, which is available had previously been washed at the blast furnaces, and as a result it is saturated with water vapor.

To conduct the investigation, one of the ten foot water bottom, hand poked and fed Morgan producers, which supplied gas to the plate mill furnaces, was selected. The steam jet blower was removed and a steam turbine driven centrifugal blower installed. At first it was decided to try mixing the blast furnace gas and air in different proportions before introducing them into the producer by means of the turbine blower. Regardless of the proportions of gas and air, a great deal of trouble was experienced with clinkers, which formed at the bottom of the producer. Gas of poor quality was also the result. It was evident that when the mixture of gas and air entered the combustion zone, combustion took place and rather aggravated clinkering conditions than mitigating them. The expected endo-thermic reaction caused by the dissociation of the carbon-dioxide constituent of the blast furnace gas in the presence of the incandescent carbon of the producer did not develop.

Changes were made in the experimental equipment in order that the air and blast furnace gas could be introduced into the producer alternately. After considerable experimentation, the proper period and quantity of gas and air blow was determined which would give no serious or objectionable clinker formation.

The following is a summary of the experimental results to date:

Kind of coal fired in producer—Illinois Kelly 4 Mine Run
Calorific value —10225 B.t.u. per lb., natural
Ultimate Analysis of Coal —Carbon — 59.15%
H_2 — 4.35
N_2 — 1.35
O_2 — 9.63
Ash — 11.80
S. — 1.10
Moisture — 12.62
Combustible in Ash — 10.10

Producer Gas Analysis

	Continuous Sample	Gas Blow Period	Air Blow Period	Blast Furnace Gas Analysis
CO_2	7.6%	7.4%	8.7%	14.0
C_2H_4	.2	.3	.2	0.0
O	—	—	—	—
H_2	6.1	8.1	6.4	3.4
CO	23.4	27.5	18.4	25.5
CH_4	2.1	2.8	1.8	.2
N_2	60.6	53.9	64.5	56.9
	100.0	100.0	100.0	100 0
B.t.u.	114.1	140.7	96.1	93.2

Continuous sample was not taken at the time as the gas blow and air blow samples.

Quantity of air blown per hour — 49,500 cu. ft.
Quantity of blast furnace gas blown per hour — 21,450 cu. ft.
Quantity of coal fired per hour — 1100 lbs., natural
Cu. ft. blast furnace gas per lb. coal — 19.5 cu. ft.
Cu. ft. air per lb. coal — 45 cu. ft.
Cu. ft. of producer gas per lb. coal — 78.0 cu. ft.

†Assistant Chief Engineer, Illinois Steel Company, South Works, South Chicago, Ill.

*Presented at Pittsburgh, May 14, 1925.

Temperature of producer gas — 1500°
B.t.u. per cu. ft. of blast furnace gas — 93.2 B.t.u.
B.t.u. per cu. ft. of producer gas — 114.1 B.t.u.

"HEAT BALANCE"

Heat Input/lb. of coal	B.t.u.	%	Heat Output/lb. of coal	B.t.u.	%
Calorific value of coal per lb.	10225	84.9	Calorific value of dry gas 78.0 cu. ft.x114.1 Btu	8900	73.8
19.5 cu. ft. of blast furnace gas per lb. coal	1820	15.1	Sensible heat in dry gas above 62°	2280	18.9
Heat in air and moisture in air not considered			Total heat of moisture in gas	393	3.3
			Heat loss — combustible in ash	195	1.7
			Unaccounted (soot, tar vapor, radiation)	277	2.3
Total charge	12045	100%	Total credit	12045	100%

Hot Gas Efficiency — 92.7%
Cold Gas Efficiency — 73.8%

The following is a "Heat Balance" of a producer using a better grade of Western coal; however, it was blown by a mixture of steam and air. The producer was operated by the regular operating crew.

Kind of Coal — Indiana, Universal No. 4—Mine Run
Calorific Value — 11141 B.t.u. per lb., natural
Ultimate Analysis — Carbon — 63.56
H_2 — 4.36
N_2 — 1.18
O_2 — 9.88
Ash — 9.22
S — 1.32
Moisture — 10.48
Combustible in Ash — 14.00

Producer Gas Analysis—
CO_2 — 8.90
C_2H_4 — .65
O_2 — —
H_2 — 10.45
CO — 19 04
CH_4 — 2.75
N_2 — 58.21

Coal fired per hour — 1155 lbs.
B.t.u. per cu. ft. of producer gas — 124.2
Cu. ft. producer gas per lb. coal — 61.5
Lb. steam per lb. coal — 0.4
Temperature of producer gas — 1650° F.
Cu. ft. air per lb. of coal — 45

"HEAT BALANCE"

Heat Input/lb. of coal	B.t.u.	%	Heat Output/lb. of coal	B.t.u.	%
Calorific value of 1 lb. coal	11141	95.9	Calorific value of dry gas	7640	65.7
Heat in steam entering producer	472	4.1	Sensible heat above 62°	2020	17.4
			Total heat of moisture in gas	757	6.6
			Combustible in ash	154	1.3
			Unaccounted (tar vapor, soot, radiation)	1042	9.0
Total charge	11613	100.0	Total credit	11613	100.0

Hot Gas Efficiency — 89.7
Cold Gas Efficiency — 65.7

Considerable has been written regarding the evaluation of gaseous fuel with respect to their use in metallurgical furnaces, particularly the relative merits of carbon-monoxide and hydrogen. The calorific value of carbon-monoxide is 322 B.t.u. per cu. ft., while the net value of hydrogen is 274 B.t.u. per cu. ft. In an excellent paper recently read before a meeting of the West of Scotland Iron and Steel Institute, by Prof. P. V. Wheeler, D.Sc., an attempt is made to evaluate gaseous fuels for furnace heating. Quoting from this paper, Dr. Wheeler makes the following statement: "A furnace charge receives the heat developed by a burning gas in two ways: in a small degree, by direct conduction from a portion of the flame itself and from the hot products of combustion; and, to the greater extent, by radiation from the flame and from the heated walls and roof of the furnace. Although carbon-monoxide and hydrogen high value have the same amount of heat, a carbon-monoxide flame radiates nearly two and a half times as much heat as a hydrogen flame burning the same volume of gas. On this score alone, therefore, a high content of carbon-monoxide is preferable to a high content of hydrogen in a producer gas for furnace work, since there will be a more effective heat transferrence if the charge by radiation and the efficiency of the system will, in consequence, be greater." Other investigators have also taken the stand that high hydrogen content in a producer gas is accompanied by high water vapor content in the gas caused by using a relatively high blast saturation temperature in the producer. The combined quantity of water vapor, that due to the combustion of the hydrogen and the vapor introduced with the blast, would mean a relatively high stack gas loss and reduced combustion efficiency.

By referring to the two "Heat Balances" given, it will be noted that there is almost twice as much heat in the moisture in the steam-blown producer as compared with the blast furnace gas-blown producer. Furthermore, on the supposition that carbon-monoxide has nearly two and a half times the radiation power as hydrogen, the total heat units released by the combustion of the carbon-monoxide and hydrogen in the gas of the test producer per hour, when compared with a like number of heat units resulting from the combustion of the carbon-monoxide and hydrogen in the gas of the steam-blown producer, would give approximately 11% greater furnace gas efficiency.

Regarding the economic aspect of coal displaced by the blast furnace gas in the producer and in the generation of steam for blowing the producer. It is estimated when based on the relative amounts of total carbon charged into each of the producers as shown by the "Heat Balance" that the blast furnace gas displaces 175 pounds of coal per hour as producer fuel and 89 pounds of coal consumed generating the steam used in blowing the producer, based on 70 per cent boiler efficiency, or a total of 264 pounds per hour. The power required for blowing the test producer, if the blower were motor driven, would amount to approximately an equivalent of 5 pounds of coal resulting in a net saving of 259 lbs. of coal per producer hour, a net saving of 20 per cent.

Only by actual operation on a furnace will it be possible to determine the relative value of the gas made by the method outlined as compared with a steam blown producer. The detrimental effect due to the greater quantity of inert nitrogen contained in the gas made by the experimental producer will be largely offset by the greater water vapor content of the steam blown producer.

No doubt much better results may be obtained by the new method of blowing if the experiments had been conducted on a mechanical producer and if a better grade of coal had been used. While conducting the investigation, the producer was operated by the regular crew and no attempt was made to give the producer undue attention. The producer bed contained the usual channels as indicated by the high gas temperature. This condition meant relative high local gas velocity through the incandescent bed which no doubt reduced the amount of dissociation of the carbon-dioxide in the presence of the incandescent coke.

DISCUSSION

W. Dyrssen:* It has been extremely gratifying to listen to this paper. I think that this method represents a big step forward in gasifying coal and we ought to be extremely grateful that the experiments made in South Chicago steel works have been published in this way so that we all may benefit from them.

I think that there has been a great deal of progress in the gasification of coal in the last few years. Mr. Chandler pointed out some interesting things last year that were very good indeed, but this paper shows us a new and different way of gasifying coal.

The cost of steam in ordinary producer practice is hardly realized. About 10 or 15 years ago the cost of steam was small as compared to the total cost of gasification, probably only 10 cents out of a total cost of over $1.00. That condition is now changed and the steam cost runs from 30 to 70 cents per ton of coal and represents usually over one-third of the total cost of gasification in a modern mechanical producer and this makes it very desirable to save the steam. The amount of useful work that the steam does in a producer can be replaced by electric power at a cost of 2 or 4 cents per ton of coal.

With Mr. McDermott's method it is possible to save the greater part of the steam cost and in addition there seems to be several other advantages, which look to me as being based on solid foundations.

I do not think, however, that experiments should stop at this point, but we should go on trying to improve this method or to find other ways. For instance, it might be possible to pre-heat the air and also the blast furnace gas. Of course, any preheating of air or gases entering the producer will add additional heat units into the gasification zone and this means that you can reduce the air that produces an excess of heat in the fire zone and increase the gases that absorb heat, which in this case, is blast furnace gas. The result would be that you could still further increase the blast furnace gas and save more coal. The preheat can easily be obtained from waste heat and I think such an experiment would be very valuable.

I want to point out also that in the use of blast furnace gas for replacing steam, we can use waste gases from one source or another for cooling the producer. Of course, that has been proposed and tried already with different success. The lack of success in some cases I think was due to the fact that the waste gases were not of uniform composition. The oxygen and the H_2O content in the waste gases varied in a too large degree. If we had a dependable source of supply of waste gases of uniform composition I think an experiment might show some very interesting things. There is one important thing to consider in waste gases and that is the ratio of nitrogen to CO_2. This ratio varies a lot with the fuel burnt. It is one thing for coal and another thing for natural gas and coke oven gas, but for all these fuels the nitrogen content in proportion to the CO_2 in the waste gases, is very high. Nitrogen is not desirable, as it cools the producer simply by absorbing sensible heat whereas CO_2 absorbs heat by transferring it to chemical heat also. I think it is important to try to get hold of waste gases with as low nitrogen content as possible. Fortunately we have such gases in the products of combustion of blast furnace gas. These gases are lower in nitrogen content than in any other waste gases and the reason therefore is that much of the oxygen in the gases is derived from the ore and the limestone in the blast furnace. Ordinary true waste gases (without excess air) contain about 2.8 parts by weight of nitrogen to one part CO_2, but waste gases from burning blast furnace gas contain about 1.8 part nitrogen to one part CO_2. In steel works we have generally such waste gases available either from boilers using blast furnace gas or the waste gases from the blast furnace stoves, and these gases furthermore have a temperature of from 400 to 600 degrees F. which sensible heat I think is all to the good for the use in producers.

The main point that I want to make is that experiments and further developments should not stop at the present point, but there are lots of things more that can be done to reduce the cost of gasification of coal and utilizing waste fuel, waste heat and waste gases.

G. R. McDermott: In connection with what Mr. Dyrssen has just said, I might say that while he was Metallurgical Engineer in the New York office of the Steel Corporation he presented an excellent paper on gas producer practice before the Iron and Steel Institute. In this paper he touches on the subject of the use of waste gas and blast furnace gas for blowing gas producers.

W. P. Chandler*: I would like to mention one point in connection with work I have done on producers. Mr. McDermott shows 8 per cent CO_2. The amount of CO_2 in any producer gas is a function of the ash fusing temperature, and where you have ash with low fusing temperature like Mr. McDermott has to work with you have to be content with relatively high CO_2 content in the gas produced. As Mr. Kneass said, if they had Pittsburgh coal with ash fusion point of 2300 to 2400°, which

*Chief Engineer, Blaw-Knox Company, Pittsburgh, Pa.

*Special Engineer, Carnegie Steel Co., Pittsburgh, Pa.

is easily obtained for open hearth producer use, the gas analysis would have been even better and lower in CO_2.

H. R. Maxon†: Mr. McDermott's able paper is very interesting to me. Each of you gentlemen have blast furnace gas. It is to your interest to use that fuel which you have immediately available in the production of steel.

The use of blast furnace gas alone is today limited practically to boilers and regenerative furnaces, such as Mr. McDermott mentions in his paper. You do not obtain temperatures of 2200° F. with it.

How can greater use be made of blast furnace gas?

With that in mind I conducted some experiments, introducing one part of by-product oven gas to five parts of blast furnace gas, each gas furnishing about 50 per cent of the B.t.u. content of the mixture. Burning this mixture with cold air, temperatures of 2500° F. were secured. One volume of by-product oven gas was mixed with only four volumes of blast furnace gas and temperatures of 2530° F. to 2600° F. obtained. With one part by-product oven gas and three parts of blast furnace gas 2750° F. was produced. This last temperature is as high as is required in reheating furnaces. If you have by-product oven gas and blast furnace gas available, by the above method the usefulness of blast furnace gas may be increased by the admixture of the higher heat value by-product oven gas, produced incidental to your operations.

The question arose—what can be done if you do not have by-product oven gas or natural gas to mix with the blast furnace gas? Experiments showed that oil increased the temperature. With 66-2/3 per cent of the B.t.u input in blast furnace gas and 33-1/3 per cent of the B.t.u. input in oil, and burning with air at 14° F. temperatures of 2550° F. were secured. Preheating the mixture to 180° F. temperatures of 2650° F. were obtained. A temperature of 2650° F. is ample for a direct fired furnace application, such as a plate mill.

By increasing the temperature obtained from blast furnace gas by the admixture of oil or natural gas, or by-product gas, you can increase the usefulness of blast furnace gas and decrease the amount of producer gas. From figures available, I believe coal burned under a steam boiler direct is equally as efficient in heat produced as gas produced from the same coal.

Therefore, if you give blast furnace gas the same value as coal, then the question of using blast furnace gas enriched is simply coal value cost of B.t.u. against cost of coal plus cost of producer operation. These fuels are easily burned.

The combustion of one, two or three gases, either enriched with oil and tar, as you have available, is not a serious problem.

A. G. Witting.* I would like to ask a question with regard to the analysis of the gas during the different periods. I presume that they are averages of a series of samples taken alternatingly during the gas blow and air blow periods, while the continuous sample was taken, or that the continuous sample should represent the proportional sum of the two averages. But how is it then possible that the continuous sample shows 10 per cent CO_2 when both of the other samples show about 8 per cent, and that the hydrogen was reduced from 7 and 6 per cent to 4.7 per cent. If the gas blow period was about two minutes and the air blow periods five minutes, we would be inclined to draw the conclusion that the average B.t.u. was rather 120 B.t.u. than 106 B.t.u. What is the explanation?

Another question relates to the total heat in the moisture given in the heat balance. In what manner was it determined?

Mr. McDermott did not explain to us how he obtained the alternate blowing periods of respectively two and five minutes and kept the ratio constant. Was the air and the blast furnace gas blown into the producer by the same blower and was any method used to maintain a constant pressure and a constant volume of the two gases blown?

Referring to the question of steam saving: As it is generally produced from waste gases or surplus gas, a greater or smaller quantity of steam for the producers really does not mean any fuel saving, but a corresponding greater or smaller waste of the surplus; you only shift the utilization of its heat value from one point to another. The value received for usefully applying blast furnace gas, that otherwise should go to waste, by directly replacing coal, is sufficiently great in itself. Only if there otherwise would be a lack of steam produced from waste products should the saving in steam by its replacement by blast furnace gas be taken into account?

G. R. McDermott: Regarding gas analysis: The continuous samples as given in the paper were not taken at the same time the gas blow and air blow samples were taken which accounts for the fact that they do not check up.

As to the moisture entering the producer, there are really three sources, first the blast furnace gas having been washed—it was saturated with water vapor, secondly the atmospheric air, of course, entering the producer contained moisture, and thirdly there is the natural moisture in the coal. Knowing these three quantities, we were able to calculate the water vapor in the producer gas leaving the producer. Furthermore there is water vapor in the gas due to the combustion of hydrogen.

The experimental machinery consisted of a turbine driven blower, exhaust steam from the turbine being discharged to the atmosphere. Valves in the air and gas mains to the inlet of the blower were alternately opened and closed by means of a solenoid under the control of a flasher type of electric switch. The gas and air entering the producer was measured by means of orifices installed in the air and gas mains. It was necessary to use a blower in order to introduce the air and blast furnace gas into the producer, discharge pressure after the blower being about 8" or 9" water.

H. W. Brooks*: There is a rather interesting technical point connected with this discussion on which frankly I cannot throw any light, but

†Pres., Maxon Premier Burner Co., Muncie, Ind.
*Assistant Chief Engineer, Illinois Steel Company, Gary, Ind.

*Consulting Engr., Fuller Lehigh Co., Fullerton, Pa.

which I will briefly point out for its possible interest to others. In the work of the Bureau of Mines, the combustion series as we here in America have always believed it to be, is as follows: $C \text{———} CO_2 \text{———} CO \text{———} CO_2$

I was rather interested last summer in talking to Dr. Wheeler of the University of Sheffield (England), whose opinion, which is shared by many other British scientists, leads to a different conclusion. He believes the series to be:

$$C \text{———} C_xO_y \text{——} \begin{matrix} CO \\ CO_2 \end{matrix} \text{——} CO_2$$

He believes that the first product of combustion is the physical-chemical complex substance C_xO_y, from which both CO and CO_2 are evolved simultaneously. All I can add to this bald statement as to the difference between our American theory and theirs in England is that what happens in pulverized fuel combustion can be explained by the British formula, while it cannot be explained by the American. The British formula may serve to throw further light on the phenomena Mr. McDermott has so interestingly described.

H. T. Watts:* I was very much interested in this paper from several standpoints. I have never been in a place where we were not able to use all of the blast furnace gas. Our great problem was to find enough blast furnace gas to do our job and to make as much out of it as possible. I am quite sure that if by any act of my own or anyone else were we able to increase the efficiency in use of blast furnace gas in a furnace by 10 per cent, we would be hailed as a hero all over the plant. It appears that Mr. McDermott has used this gas and not lost any heat. In the first place, he has demonstrated he has not increased the waste gas loss on the furnace itself, and by introducing 21,000 cu. ft. of gas per hour, he has replaced 175 pounds of coal at the producer. That is just about 100 per cent recovery. Of course, we have never been able to equal anything like that in our boiler practice. It would seem that this scheme if applied generally to blast furnace gas would rather revolutionize our practice. As a matter of fact, we will never have enough producers to utilize all the gas. One producer will take all the gas produced in the production of about 3 tons of iron per day.

I think this subject is going to bear some close study, because as nearly as I can see, it shows the most efficient use of blast furnace gas. In this case, I think he has been able to get what appears to be a very high recovery because of the increased efficiency in the use of coal in the producer.

A. G. Witting: It seems to me Mr. McDermott has never talked about the efficiency of the gas in this paper at all. He don't mention how many B.t.u.'s per ton of steel he used with his blast furnace producer gas and with straight producer gas; was any comparison obtained on pounds coal equivalent per ton steel?

Martin J. Conway†: Mr. McDermott's paper points to a tangible saving over the present method of coal gasification. The chief saving is of course the steam saving. The present method of installing turbine-driven blowers does not in all cases benefit the operation very much. For instance assuming that for a certain coal, the necessary amount of steam to be used to keep the clinker down in the producer is .4 pounds of steam per pound of coal gasified. With a turbo blower it is possible to supply the necessary amount of oxygen for gasification with .2 pounds of steam per ton of coal gasified. In order to keep away from excess clinker it is then necessary not only to use the exhaust steam from the turbo, but to bleed a like amount of live steam as well, and therefore the result is that we wear out a very efficient turbo blower in obtaining what could be supplied by a multi-stage set blower, this of course within the range of 3,000 pounds of coal per hour. The other saving which stands out in Mr. McDermott's paper is the conversion of CO_2 to CO. The deciding factor after the steam saving has been accounted for is whether in the average steel plant it is advisable to take the blast furnace gas from the boiler plant to be used on furnaces at a reduced unit efficiency.

G. R. McDermott: As we have only one experimental producer operating in this method, we do not make sufficient gas to determine its merits in a furnace. As long as the blast furnace gas is a surplus, it is displacing its B.t.u. value in coal at the producer and furthermore, it is displacing the coal used in generated steam required for blowing the steam blown producer. The fact that no troublesome clinkers are produced indicate that the expected endo-thermic reaction is taking place. The gas in other words is a refrigerant due to the dissociation of CO_2 into CO in the presence of incandescent carbon. The test on the steam blown producer was selected from another investigation and represents our practice when using Indiana coal on a hand fed and hand poked producer. It was selected to give a comparison between the two methods of blowing a gas producer. As mentioned before, we were discharging blast furnace gas to the atmosphere and it was necessary to develop other uses for blast furnace gas which led to this experiment.

*Steam Engineer, Otis Steel Company, Cleveland, O.

†Fuel Engineer, Wheeling Steel Corporation, Steubenville,, Ohio.

IRON AND STEEL EXPOSITION

Philadelphia Commercial Museum

Philadelphia, Pa.

September 14-19, 1925

For Space Write

IRON AND STEEL EXPOSITION

706 Empire Bldg. Pittsburgh, Pa.

Generation of Steam From Coke Breeze*

By JOHN VAN BRUNT†

I FULLY appreciate the privilege extended to me to talk to you on the subject "Generation of Steam from Coke Breeze," but I feel that anything I may say will be much like shipping coal to New Castle. You, gentlemen, at least those of you in the steam generating department, undoubtedly know more about this subject than I do. Some of you are both making coke breeze and burning it, while I am in the business of selling stokers or grates on which coke breeze may be burned.

My introduction to this subject was in 1915. My company had just completed a trial installation of a Coxe stoker at the Edgewater, New Jersey, plant of the Corn Products Refining Company. This was the first installation of a controlled divisional forced draft chain grate stoker outside of the anthracite mining territory.

You may be interested in knowing a little of the early history of the stoker which was the invention of Mr. Eckley B. Coxe, a well known anthracite operator. Mr. Coxe and an associate, Mr. Richards, took out a considerable number of patents between 1892 and 1893. Installations made in some of the collieries proved that this type of stoker was well adapted to anthracite coal of the smaller or steam sizes, known as Rice or No. 2 Buckwheat and Barley, or No. 3 Buckwheat. A study of Mr. Coxe's patents shows that he had a thorough appreciation of the requirements of a stoker to burn that particular fuel.

In 1911 or 1912 the Coxe Traveling Grate Company was organized by Mr. William Lloyd and a number of stokers sold in the anthracite territory. The Combustion Engineering Corporation shortly after secured the exclusive sales agency for all the country outside of the anthracite counties, and the first sale was made to the Corn Products Refining Company.

From observation of this stoker burning anthracite we felt sure that coke breeze could be burned equally well, and through one of our organizations the engineers of the Tennessee Coal and Iron Company were interested in the possibility. One or two carloads of coke braize were shipped from Alabama to Edgewater and successfully burned on this stoker. There was some uncertainty as to whether the low volatile content of 2 per cent would make ignition difficult, if not impossible, from a practical standpoint.

On the performance at Edgewater the Tennessee Coal and Iron Company in 1915 purchased three Coxe stokers 9'-8" by 12'-6" of 120 square feet area each, which were installed under 500 horse power Rust boilers. From tests which were made on these stokers I have tabulated the most pertinent data—ratings of 150 per cent and a peak of 200 per cent were secured. The breeze used was screened through a ¾" or ⅝" round hole screen. To the best of my knowledge, that was the first successful attempt to burn coke breeze on a mechanical stoker under a power boiler of an considerable size, and to the engineers of the T. C. and I. R. R. Co., should go the credit of being the first men to successfully burn this fuel and operate a boiler plant wholly on coke breeze.

You steel men are in better position to know the relative value of coke breeze in 1910 and now, so I will not attempt to put a value on this accomplishment. That it had value was evidenced by the number of sales made subsequent to that date. This first installation was quickly followed by others made at the Seaboard By-Products Company, Youngstown Sheet and Tube Company, Jones and Laughlin, Semet Solvay Company, Milwaukee Coke and Gas Company, Otis Steel Company and many others including the Carnegie Steel Company's Clairton By-Product Plant which is, undoubtedly, the largest plant in the world fired exclusively with coke breeze.

At that time we presumed that coke breeze was a definite fuel as to size and volatile content, but we found out very soon that every plant had its own particular sizing. I recall one installation which need not be named. On the completion of this installation the fires were started with considerable difficulty and would in a short while go out. Receiving a request for assistance, the writer took the first train to the plant. The difficulty was soon apparent. It was due to the large percentage of coarse lumps. In this plant coke breeze was all that passed a 1" bar screen and some of the bars were warped or bent at that. As a result, much of the coke was in fingers 2" to 3" long and some sized 2" x 2" x 4". The larger sizes naturally gravitated to the outside of the stoker while the fines went to the center. This incident led to a specification of sizing of the breeze. Our specification now reads—all to be screened through a ⅝" round hole screen with not less than 20 per cent dust.

The question may arise as to why the sizing of the fuel is of such importance. Those of you who have had experience with free burning bituminous coal in traveling grate stokers will appreciate the necessity of correct sizing. Sizing determines fuel bed thickness, draft loss through fuel bed and, to a great extent, the rate of ignition. Large sized fuel requires a thick fuel bed, fine fuel a thin bed. Coarse fuel ignites slowly and has low resistance to the air through the fuel bed, while fine fuel ignites more readily and has more resistance to the air. If large and fine material is mixed, it is practically impossible to prevent segregation of the coarser lumps from the fine, particularly in the hopper of a stoker.

The larger lumps will predominate along the sides of the grate. This changes the nature of the fuel bed across the stoker so that the resistance to draft will be less along the sides than in the center. For any given air pressure under the grate more air will pass through grate at the sides than in the center. The larger fuel at the sides ignites more slowly because of its size; that is, because there is less surface exposed per unit of mass than is the case with smaller fuel. The additional air that passes through the coarse material further retards ignition because of its cooling effect. This action is much more marked with coke breeze

*Presented at Pittsburgh, May 14, 1925.

†Vice Pres., in charge Engineering, Combustion Engineering Corporation.

than with bituminous coal. Hence, the necessity of a closer range or spread between the largest and smallest fuel particles in the case of coke.

In our work with anthracite we have seldom encountered any troubles due to sizing except in a few cases where yard screenings were burned or where the fuel contained a very large proportion of extremely fine fuel. In the latter case the difficulty was solely that of increased losses due to the large amount of fine material. A parallel case with coke breeze will be found in what is known as "pit breeze" or that material which is dredged from the sump pits which receive the quenching water.

The next point is that of ignition—how obtained, and what constitutes stable or satisfactory ignition. Ignition is obtained in the usual furnace or stoker setting solely by heat radiated and reflected from the arch and side walls of the furnace, principally the arch. To obtain early ignition the incoming fuel, as soon as it passes the gate, must "see" the greater portion of the arch; that is, the incoming coke must not be shaded from radiation by a deep curtain wall or short low arch. At the same time, the incoming fuel should be shaded from the cooler surfaces of the boiler, else the radiation from the freshly ignited fuel to the boiler surface will result in cooling and retardation. Experience has shown that for coke breeze or other low volatile fuel, the arch should cover about two-thirds of the grate. Whether more or less, depends on the location of the boiler surface in relation to the grate.

Generally speaking, if on a setting drawing we draw one line from the point of incoming fuel to the end of the arch, and another line from the same point tangent to the so-called ignition arch, more properly the curtain wall, and intersecting the under side of the arch at a point three feet or thereabouts from the front of the furnace, these two lines will form a triangle, the upper side of which is the under side of the arch and the angle formed between the two lines is a measure of the effective radiation. From this angle should be deducted the angle formed by two lines drawn from the same point to the extreme point of the boiler heating surface that can be seen from the ignition point. This angle represents re-radiation. The difference between these two angles is a measure of net ignition value.

The arch must be very hot and kept hot by active combustion under it. Therefore, it is desirable to start active combustion as quickly as possible so that hot gas will sweep the arch and an incandescent fuel bed will radiate heat to the arch. In order that combustion may be maintained under the arch, there must be enough space for mixing. Therefore, the arch must not be too close to the grate. At the same time bear in mind that the higher the arch the longer it must be.

The principal losses in any stoker operation are unburned carbon and that due to excess air in the flue gas. On the forced draft traveling grate another loss may be in delayed combustion due to lack of mixing or stratification of the gases.

On fuel containing a large percentage of fines the carbon loss; that is, unburned carbon carried into the boiler or into the ash pit, may be very considerable. In our work with anthracite coal we have found that this loss can be materially reduced and at the same time better mixing and a higher average CO^2 obtained by a change in furnace design. This change consists in the use of two arches, one short arch at the front end of the grate and a long sloping rear arch extending from the ash pit wall forward to within three feet of the front arch.

This construction involves a change in operating methods; that is, the air pressure under the grate is usually lower in the front end and higher toward the rear. The combustion under the rear arch causes a flow of gas forward at a fairly high velocity. This gas carries the fine carbon blown from the fuel bed and drops the carbon on the front end of the grate. Any air which may leak through the ash pit or under the stoker must pass over the fuel and through the narrow throat between the two arches. At this point there is a thorough mixing of the gas from the front end of the stoker which contains considerable CO and that from the rear which carries excess O. The result is a high average CO^2. While this construction does not eliminate the carbon loss the reduction is quite material and in the case of anthracite has resulted in an increase in efficiency of from 3 to 5 per cent at corresponding combustion rates.

An installation of this type is more expensive than the earlier settings. The boiler must be set very much higher and the arches and necessary supports are more costly. The application can seldom be made satisfactorily on existing boilers, although some compromise is usually possible.

The recent development of the air pre-heater should be of great interest to those desiring to burn coke breeze to better advantage and at high efficiencies. I believe that it is easily possible to secure an overall efficiency of stoker, boiler and air preheater with coke breeze at 80 per cent. At the same time, a more stable ignition would be obtained by the use of preheated air.

In the average installation air can be preheated by the boiler gas to 250 deg. or 300 deg. which is a direct gain of 4 per cent to 7 per cent, depending on the CO^2. There is also an indeterminable gain due to better combustion which, in the case of bituminous coal, may amount to 1 per cent or 1½ per cent. With coke breeze this indeterminable gain may not be as much, as the heated air will not be likely to affect the physical character of the fuel bed.

Preheated air will have but little effect on the upkeep of the stoker unless the fuel be such that clinker will melt and adhere to the grate. Due to its abrasive nature, the wear on chains, skids and sprockets is higher than where coal is burned, all of which must be considered when purchasing stokers for this purpose.

I know of no other satisfactory method of burning this fuel. Pulverizing has frequently been discussed, but because of its hardness and abrasive qualities the pulverizing cost would be very high and as compared to a well designed stoker installation with preheated air I doubt if the efficiency would justify the additional investment and increased operating cost.

At the present time approximately 200,000 rated

horse power of boilers are fired with coke breeze on Coxe traveling grate stokers, some of which have been operating ten years.

I feel that from this fact I may argue that coke breeze is a suitable fuel, not only for steel plants which are close to an adequate supply, but for gas and coke works and other plants able to draw upon any surplus of such fuel available.

Coke Braize *

By G. C. EMMONS†

IT is a source of great pleasure to me to be called upon to address so fine and wide-awake an organization as I know the Association of Iron & Steel Electrical Engineers to be.

But it is both with pleasure and regret that I stand before you today, pleasure at the honor that you have conferred upon me in inviting me to address you and regret that I have not a great deal to present that may be of great interest to you. We have not made hundreds of tests on various types of installations nor have we made a hobby of coke braize.

Frankly, I believe that there are several among your membership who are more qualified to present a paper on this important subject that I. To those gentlemen what I have to say will doubtless be rather dry. I have no expectation of being able to present to this body any new and startling advancement in the art. My only hope is that I may be able to, in some way, help those of you who have not as yet faced this problem, by presenting my experiences so that they may be made use of in avoiding the difficulties that are encountered with the burning of coke braize.

In 1912, the United States Government made a serious attempt to economically utilize braize in a slagging type of gas producer, but although the experiments gave considerable promise, it has never been employed on a commercial basis.

Coke braize is unquestionably the most difficult fuel that we have to handle in this district. Not only does it present several of the problems that we encounter with other fuel, but it presents them in an intensified degree, and in addition presents at least one very serious problem, viz., ignition, that is peculiar to the burning of coke braize.

In the combustion of bituminous coal, the only other solid fuel that we have to deal with in this district, we, of course, encounter the ever present problem of furnace maintenance. In order to maintain ignition in some of the older types of overfeed stokers, such as the Roney, it was necessary to employ ignition and combustion arches and customary to employ a bridge wall rising shear upon the dumping section. Thus the furnace was very closely "bottled up" with the result that the combustion and especially the ignition arches received severe punishment. When the underfeed stoker was first employed, arches were used, but as the science developed, engineers recognized that arches were not required to obtain ignition with bituminous coal on this type of stoker. At this stage of the art, although the arches had been eliminated, the vertical bridge wall was still employed at the end of the dumping section. As we constantly went to higher ratings, our furnace maintenance increased, for the bridge wall produced quite a "bottling up" action, particularly at high ratings. But with the advent of the radiant heat furnace, Fig. 1, in which the lower rows of boiler tubes are exposed throughout their entire length, the problem of furnace maintenance has been greatly reduced, even in the face of ever increasing boiler ratings. This has been due mostly to the fact that the furnace temperatures encountered are not excessive, and our experience at least, has shown that not only are moderate furnace temperatures obtained with a properly designed radiant heat furnace, but that this temperature is practically independent of the boiler rating.

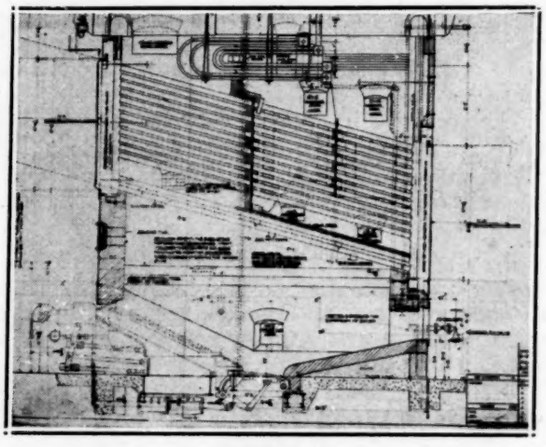


FIG. 1

Although bituminous coal which contains some forty or more per cent volatile does not require arches when burned on an underfeed stoker, still when we have to deal with coke braize, a fuel containing 3½ per cent or less volatile, we have such a difficult problem of ignition that, despite the fact that we do not wish to employ arches, we are absolutely compelled to do so, and adopt to a very large extent the practice that we have been so diligently getting away from, namely, the "bottling up" of the furnace by means of arches.

Many attempts have been made to burn coke braize on underfeed stokers with the same settings that have been employed on bituminous coal. These have not, I think we can safely say, been generally very successful, for when burning coke braize straight on underfeed stokers, we failed to get any rating worth mentioning in modern practice and in addition we have a very high stoker maintenance due to the

*Presented at Pittsburgh, May 14, 1925.

†Steam & Efficiency Engineer, Republic Iron & Steel Co., Youngstown, Ohio.

very great abrasiveness of coke braize. In our practice we have entirely abandoned any hope of burning coke braize straight on our underfeed stokers. We have, however, and do, burn mixtures of coke braize and coal and have burned as high as 50 per cent by volume coke braize and coal, but our usual practice is to burn in the neighborhood of 20 to 30 per cent coke braize with coal. This practice is, as I have said, accompanied by excessive stoker wear due to the abrasiveness of coke braize, and it is this condition that has caused our stokers when burning a mixture of coke braize and coal to wear the bottom of our ram boxes clear through. We now use a ram box of rectangular cross-section which has a renewable bottom liner and renewable throat liners. The bottom liner is not only renewable, but likewise, adjustable, so that as the clearance between the ram and ram-box increases and therefore the sifting increases, the original alignment can be regained by shiming up the ram box liner.

Although in our underfeed practice, coke braize can be burned on this type of stoker, it is not done very successfully. This is partly due to the fact that the braize we use on our underfeed house is not merely by-product screenings, for we obtain it by rescreening our blast furnace coke at the furnaces. It, therefore, contains considerable iron ore, which also increases the furnace and stoker maintenance. When using large per cents of this coke braize or blast furnace coke screenings, we have produced little rivu'ets of iron running down our stokers. When burning bituminous coal we were able to prevent the guttering out of our front walls immediately above our stoker tuyeres by employing carborundum brick at this point. However, when we burn this mixture of bituminous coal and coke braize containing iron ore, our car-

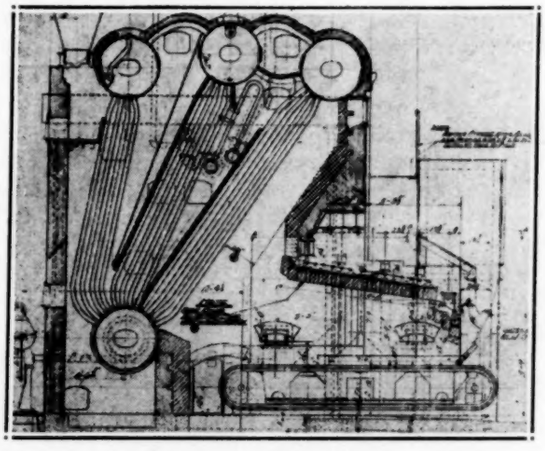


FIG. 2

borundum brick wasted away more rapidly than fire brick. We were able to overcome this problem by substituting alundum brick for carborundum.

These difficulties with underfeed stokers have led to the almost universal adoption of stokers primarily designed for burning coke braize. This type of stoker is known as the forced draft chain grate. We will now consider the important features in the obtaining of a satisfactory installation. At Youngstown our first furnace arrangement is as shown in Fig. 2.

We found with this installation, that we were able to obtain very satisfactory ignition as long as the volatile was approximately normal, namely, 3.6 per cent, but when the industry slowed up and we therefore no longer had the requirement for short coking time, and we were forced to lengthen out our coking period in order to keep all of our ovens hot, for by-product coke ovens cooling off goes a great way towards wrecking the equipment by means of cracks due to temperature changes. These long coking times naturally result in the lowering of the volatile constituents, and we found that when this volatile got down to in the neighborhood of 2.46 per cent, we began to experience difficulty in ignition. This became so seri-

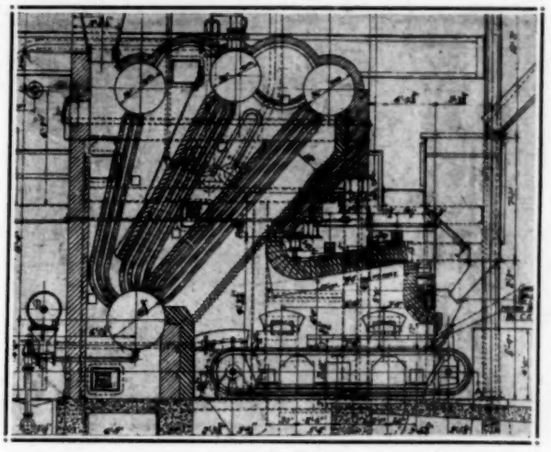


FIG. 3

ous that we were forced to employ plus pressure and to mix bituminous coal with the braize in order to keep our fires alive. This, at first hand, might seem to be a very satisfactory remedy, but in reality it is not, for in our case at least, where no special provision has been made for homogeneous mixing of the two fuels, a poor mixture is obtained and our stokers sometimes have quite clearly defined strips, or islands of bituminous coal. These, of course, are very much freer burning than the braize, with the result that they burn out long before the braize and produce holes in the fire which is obviously detrimental. Even if quite effective mixing is obtained, this difficulty would still be present, but to a less degree, for if we run our fire fast enough so that our coal is burned out just before it goes over the back of the stoker we then have not yet completely burned out our coke and we obtain a high ash pit loss.

Firing straight braize, we can obtain with a given furnace setting quite a satisfactory ash for this type of setting, but if instead of firing coke braize we do not screen out our domestic coke which are coke sizes of about the size of a small walnut, and fire this mixture, we found a condition very similar to the firing of coke braize and bituminous coal, namely, if we run our fire so as to get a good ash on the coke braize, the relatively larger sizes of domestic coke have not burned out and therefore give us a bad ash condition. This condition might be considered as inherent, so we come to the conclusion that in order to obtain proper ash pit losses, we should not fire mixtures of coke braize and domestic coke, but should fire either one or the other. The more satisfactory results are ob-

tained with the firing of straight braize rather than the firing of straight domestic coke.

In an attempt to increase the ignition, our second installation was made with the combustion arch pitching downward toward the back.

Our thought in advancing this design was that the radiant heat reflection would be concentrated toward

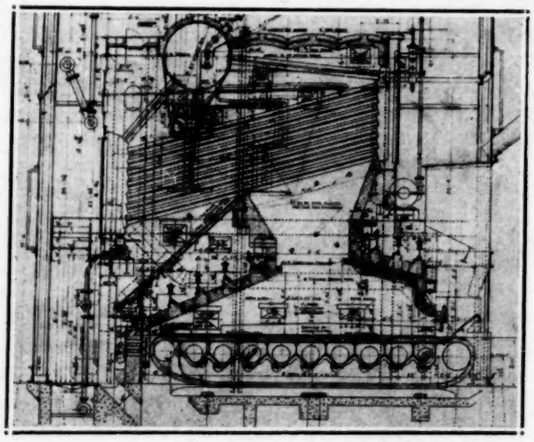


FIG. 4

the front of the furnace where ignition is required. We were not able to discern any very marked improvement by this pitching of the arch. The theory, of course, was very pretty, but in practice instead of your arch presenting a plane surface such as the drawing shows, the arch soon becomes rough and wavy, so it is very questionable in my mind at least that this downward pitch of the combustion arch is of much advantage.

On our last installation, which is unquestionably our best, we have employed a rear arch as well as a

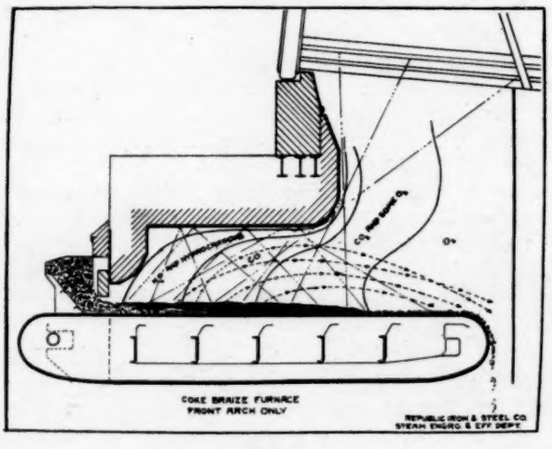


FIG. 5

front arch. You will not that the front arch is very much shorter in this than in our original installation, it being 4′7″ as against 9′. This reduces the punishment which the front arch receives, for although ignition normally occurs near the front of the front combustion arch, the hottest part of the fire is towards the rear of the front combustion arch.

We find that the problem of burning coke braize successfully is almost wholly one of proper furnace design. Let us examine the conditions that exist in different types of furnaces.

Fig. 5 illustrates what actually occurs in a furnace having but a front arch. The fine dust is blown off the grate with a high pressure at the front of the stoker and much of this fine dust is blown over into the ash pit.

Note that the water vapor and hydrocarbons rise from the front end of the stoker. This is followed by a zone producing principally carbon monoxide (CO) and towards the latter part of the stoker the third zone is found wherein carbon di-oxide and some oxygen is liberated, and in the fifth zone oxygen alone rises. This type of setting does not mix the gases well with the result that the gases rise stratified.

In addition to these other two faults, this type of setting will not ignite and burn low volatile braize without carrying a positive pressure in the furnace which results in high furnace maintenance.

Fig. 6 shows a design of one of the stoker companies that was made in the summer of 1923, or at

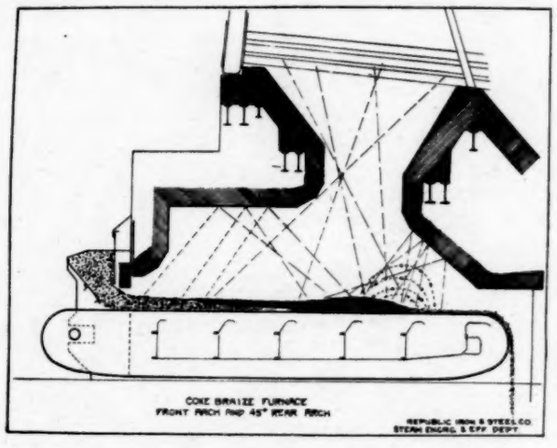


FIG. 6

about the same time that we also designed and built our front and rear arch setting. The design shown in this figure having a rear arch at an angle of 45 deg. is made with the expectation of reflecting radiant heat from the front of the setting on-to the rear of the grate in order to burn out the ash more completely. This not only accomplished its object, but in addition it improved the gas mixing.

After a very extensive investigation and experimentation, one of the leading stoker companies also arrived at the design shown in Fig. 7, which incorporates their best ideas on this important subject, and is practically identical with the design we originated in 1923, both employing rear arches sloped at approximately 20 deg.

As will be seen from this figure, the hydrogen and hydrocarbons rise in the first zone and are then followed progressively by the generation of carbon monoxide; CO_2; and oxygen. There is, however, a very distinct difference in the performance of this type of setting, particularly if, as they advocate, rear firing is employed. For the lean gases from the rear are then projected forward by the forward direction given to them by the rear arch. This results in these gases intimately mixing with the rich gases from the front,

and the best gas combustion is therefore obtained with this type of setting.

As in the case of the single front arch, the fine material blown up in front of the setting is directed rearward. However, the gases rising from the rear of the stoker are compelled to travel forward, thus carrying forward with them the fine particles blown

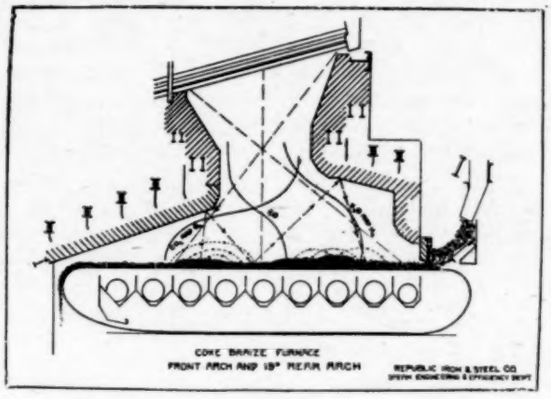


FIG. 7

off the grate at the rear. This condition results in far less fines being carried over into the ash pit, and therefore results in a much better ash than is obtainable with the same degree of operating skill with a front arch design.

Unquestionably the most valuable single feature of the front and rear arch design is its improvement of ignition, for with this type of setting it is possible to ignite and maintain ignition on straight low volatile braize without carrying a positive pressure in the furnace. This cannot be accomplished on single or front arch settings.

This type of setting, therefore, accomplishes three very valuable results, viz.: 1st, much better gas mixing and gas combustion; 2nd, much improved ash; 3rd, very much improved ignition without back pressure, and therefore, with lower furnace maintenance.

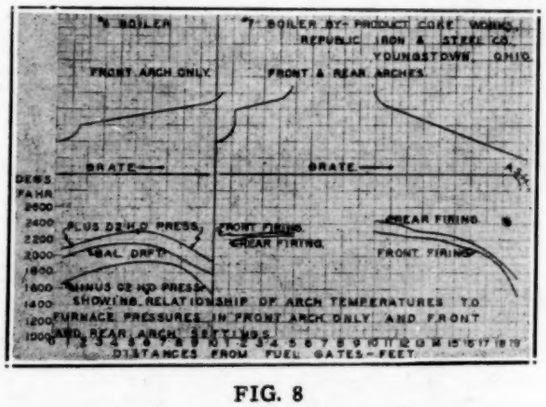


FIG. 8

Fig. 8 shows the temperatures of the faces of our arches. The left of the cut shows the various arch face temperatures obtained on our front arch setting. It will be noted from the lower curve on the left of Fig. 8 that when carrying a negative pressure of .02" water, the temperature rose from 1640 deg. F. at the front to a maximum of 1920 deg. F. 6.5" from the front of the stoker. Incidentally under this condition we lost the ignition. The second curve is temperatures obtained with balanced draft and shows that the temperature rose from 1960 deg. F. at the front to 2135 deg. F. The third curve is obtained with a positive pressure in the furnace and shows that the temperature rose from 2070 deg. F. to 2300 deg. F.

On the right hand of Fig. 8 are plotted the arch face temperatures of our front and rear arch furnace. These were obtained with a negative pressure under the front arch of 0.01" H_2O in both cases. One curve represents temperatures obtained with front firing and the other those obtained with rear firing. The temperatures in the first case rise from 2250 deg. F. at a point one foot back from the fuel gate to a maximum of 2300 deg. F. on the front face of the rear arch. The maximum temperature on the face of the

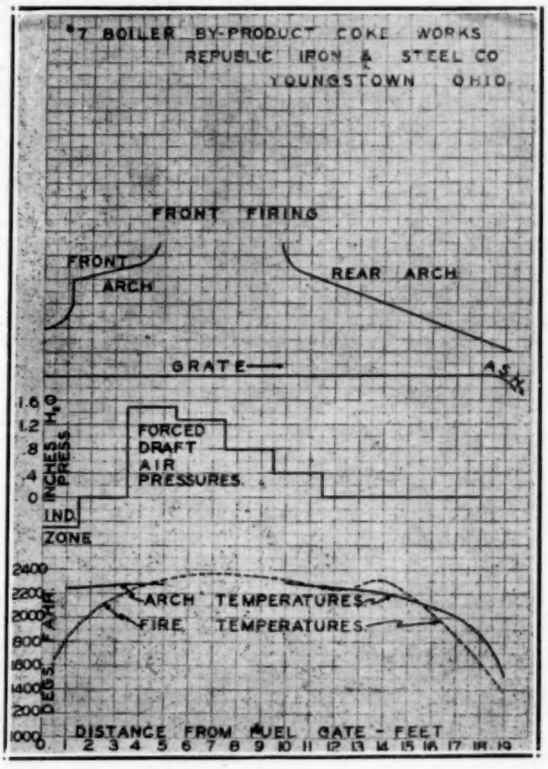


FIG. 9

main arches is 2285 deg. F. obtained both at 4′ and 5′ back from the fuel gate.

With rear firing, the temperatures rise from 2141 deg. F. one foot back from the fuel gate to a temperature of 2430 deg. F. at the front of the rear arch.

Table 1, compiled from Fig. 8, shows the arch face temperatures on the first ten feet of arch in both types of settings.

TABLE 1

Type of Setting	Furnace Press. In. H20	Front Temp. Deg. F.	Max. Temp. Deg. F.	Avge. Temp. Deg. F.	How Fired
Front Arch	-0.02	1640°	1920°	1812°	Front
	0.00	1960	2135	2030	Front
	+0.02	2070	2300	2175	Front
Front and Rear Arch	-0.01	2250	2285	2236	Front
	-0.01	2141	2430	2308	Rear

It is interesting to note from Table 1 that even with a slight negative pressure under the front arch,

the front and rear arch design gives not only as high a temperature as the front arch design when operated with an injurious positive pressure, but that its average temperature is from 61 deg. F. to 133 deg. F. higher than the front arch design. This is positive proof of the merit of this design over the front arch design.

Fig. 9 shows the pressures in the separate windboxes together with the fire bed temperatures and the resulting arch temperatures when the boiler is front fired. The first zones are under negative pressure, this being the induced draft section.

Fig. 10 shows the pressures in the separate windboxes together with the fire bed temperatures and the resulting arch temperatures when the boiler is back fired.

It is interesting to note from Figures 8 and 9 that, although the fire in one case attains a temperature of

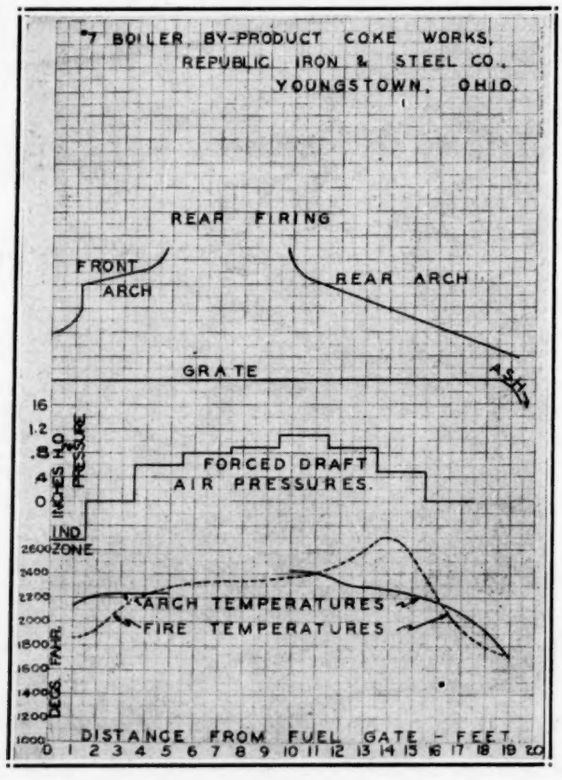


FIG. 10

2700 deg. F., the maximum arch temperature in no case exceeds 2420 deg. F.

Table 11 is a resume showing comparative results on the three types of furnaces discussed.

TABLE 11

Furnace Number	1	2	3
Size of Stoker	12x14'	10x17'	12x14'
CO2	10.2	14.2	15.2
O2	9.8	5.7	4.4
CO	0.0	0.2	0.25
Combustible in Ash	40-45%	9.67%	10.56%
Combustion Rate	28.4	29.3	32.9

Key to Furnace Design—
No. 1 Front Arch and Straight Rear Bridge Wall.
No. 2 Front and Rear Arch (Rear at 45° angle.)
No. 3 Front and Rear Arch (Rear at 20° angle.)

Note particularly the big improvement in the combustible of the ash between the front arch and the front and rear arch. You will note that the combustible in the ash has fallen from 40-45 per cent to approximately 10 per cent. These you will note are results of approximately the same combustion rates, viz., 30 lbs. per effective square foot per hour.

Recommendations or Suggestions.

In closing, gentlemen, I will make a few recommendations, or suggestions.

(1) Be sure that the stoker is set up square and level, otherwise side crowding will occur and breakage is almost sure to follow.

(2) Use a front and rear arch setting, instead of front arch only. Use a slope of 18 deg. to 20 deg. on the rear arch.

(3) Avoid the use of long front arches.

(4) Use suspended arches front and rear, do not crown them, make them both perfectly flat.

(5) Don't entirely depend upon holding the ignition arch by means of the steelwork built into it. Tie it up with rods on about 2' centers to an I-beam several feet above where the ignition arch and main combustion arch meets, as it is very difficult to maintain a tight seal at this point, and if this is not done and plus pressure is ever carried, leakage will cause overheating of the steelwork at this point and result in sagging or warping of the ignititon arch which usually jams the fuel gate.

(6) Use a rear slide construction made up of steel plate riveted together, on the top of which lay one course of red brick; on top of which lay closely fitted asbestos board; and cover this with cast-iron plates ½" thick.

(7) When using a rear slide construction be sure to prevent sifting at the top of the boiler slide.

(8) Prevent sifting at the sides of the slides by running the sides of the slide into the side walls 4".

(9) Leave the space between the rear arch and the rear slide entirely opened. Periodically inspect it for siftings.

(10) Provide plenty of furnace inspection doors.

(11) Provide a dripping hopper if possible.

(12) Use high pressure side wall coolers.

(13) Control the furnace pressure by the automatic regulation of Louvre dampers between the stoker windboxes and the main air duct. After obtaining the desired windbox pressures by means of adjusting the windbox dampers, open wide the dampers to the windbox carrying the highest pressure and readjust the other windboxes to re-establish the original blast pressures. This causes the throttling of the air to be almost entirely accomplished by the Louvre dampers, and prevents the burning out of the center of the fire by the velocity head of the blast air.

DISCUSSION

F. G. Cutler*: Mr. VanBrunt indicates that all of the credit for the first installation on Coke Braize as being due to the engineers of the Tennessee Com-

*Chief, Bureau of Steam Engineering, T. C. & I. R. R. Co., Ensley, Ala.

pany. I want to qualify that by saying that credit is also due his organization in recognizing a good thing and taking it up at the time they did, and also to our management in risking their company's money in making the first installation. Very often companies are prone to be conservative and not do much pioneering, but in this way and by a fortunate combination of circumstances we were able to use up a pile of 100,000 tons of coke braize that was a drug on the market. Incidentally, we have found it necessary at times to burn coal on these coke braize stokers. There are times when we are short of coke braize and have to keep the mills going, so we burn coal in the same stokers and fire it without any particular change in the system.

H. T. Watts*: I haven't anything of any great value to say, but would like to ask the gentlemen that spoke this morning so ably, what they do about their side wall construction. I remember one case in which water boxes were used on the side wall up as high as the level of the fire, and another case in which carborundum brick was used. I have had cause to think lately that I would rather have the water box than carborundum brick. I would like to know what present practice along that line is.

At one time when we were conducting tests, we undertook to measure the heat which was absorbed by the water and found it to be 2½ per cent. I should think that heat could easily be taken care of about a power plant. It is objectionable to conduct water to some other point, but if people are not having any better luck with carborundum brick than we are, I think we had better go back to the water box.

John VanBrunt†: I see no objection. I think there is a decided advantage is using rectangular water boxes on the side walls. The heat absorbed is about 2½ per cent. The rectangular water boxes can be connected into the boiler circulation, and if the water is clean, you need not expect any trouble with them. The slope should be 1 inch in 12 feet, or perhaps slightly more; from the front rising toward the rear; the inlet being at the front, the outlet going up in the boiler setting. Under these conditions you may expect no trouble. The Commonwealth Edison Company put such water boxes above the grate level, preventing clinker from sticking to side walls.

Carborundum brick is not suitable for bituminous coal, but is quite satisfactory with anthracite. The best solution is unquestionably rectangular water boxes. The construction is not difficult, except where the box goes in at the front of the furnace. The price of the equipment is rather high. Boxes 9″ x 7″ with ¾″ walls are quite expensive pieces of equipment, but I think they are well worth the price, and we recommend them where the customer is willing to spend the money.

H. T. Watts: On one of those tests, some of you perhaps noticed we showed a volatile component of 11 per cent in the coke braize. We don't make that kind of coke at Otis Steel Company. It happened to be the first of three tests that were run, and, unfortunately, we had a small quantity of bituminous coal mixed in. We were very careful in the sampling operation, and I am sure the results shown were right.

I was interested in remarkes made about pulverized coke braize. We have a condition in which it would be to our advantage to use pulverized coke in our boilers as auxiliary fuel to blast furnace gas, having installed powdered coal equipment. This was installed principally to take care of our power requirements at such times as the furnaces were down. Since we added this power unit to run the mills, it so happens that we seldom need the powdered coal equipment to carry our load, the blast furnace gas being quite sufficient. There are times, due to occasional furnace irregularities when we would like to burn auxiliary fuel for perhaps half-an-hour. I do not believe it is feasible to keep a supply of powdered coal for say a month's time and expect it to function when you want it at a moment's notice. It occurred to us that coke braize would more readily adapt itself to the situation., It may be true that it is not preferable to burn pulverized coke braize as compared with the cost of burn-straight braize on a stoker. But since we have the equipment on hand, it occurred to us that we might as well pulverize our coke braize and have it in waiting for any such emergencies. I was strongly advised not to try the experiment on account of the abrasive action of the braize. We have temporarily abandoned this plan, but I was interested in remarks made today, and still think this fuel would serve admirably in our case.

William Pestell*: We have only recently taken over the Harrington stoker and the writer has had little personal contact with it yet, so that he is not in a position to add much to what has already been said. We do subscribe to what Mr. VanBrunt has said with regard to water cooled side walls. We find that for coke braize, carborundum or any other brick that we know of is not a sufficient protection to prevent sticking of clinker and that water cooled boxes are the only thing. It is, of course, necessary to have clean water in order that the up-keep on the water boxes will not be excessive.

We have done a great deal of research work on furnace design, particularly with reference to our construction and I believe we are one of the first to use the 20 deg. rear arch, which Mr. Emmons mentioned, and which was used by him about a year before our development.

John A. Hunter†: We do not have any coke braize, but several years ago, and I believe a year or two before Mr. Cutler made his first installation, we experimented with it on underfeed stokers. We succeeded in burning it quite successfully, but the fires had to be handled very carefully to get good efficiencies and capacities from the boilers.

The coke braize was obtained from a bee-hive coke oven plant of the Frick Coke Company. The quantity used was relatively small so that the cost of loading was high and this with the freight rate made the price per ton approach that of coal. When using coke braize there was considerable dust around the works, and this being very abrasive tended to

*Steam Engineer, Otis Steel Co., Cleveland, O.
†Vice President, Combustion Engineering Co., New York.

*Vice President, Riley Stoker Corporation, Worcester, Mass.
†S. & S. Engr., American Sheet & Tin Plate Co., Pittsburgh, Pa.

mar the surface of the sheets which we manufacture, and for those reasons it was decided to abandon its use.

F. G. Cutler: We were operating on a Parson system before we went to the Cox.

Walter N. Flanagan*: I would like to say a word about the use of carborundum brick. It is all right to use water box on chain grate stokers if you have good water. Where you don't have good water, there is only one thing to do, that is, run at low pressure and waste heat, unless it can be used for that water. I would like to ask if anybody in the room has had experience and to hear what the trouble is with carborundum brick and why it is not almost as successful as water box. There are some experiments in burning coke braize on under-feed stokers. We are not burning it very fast and are not finding it necessary to carry pressure in fire box at all. We cannot carry high heats on the braize. When mixed with coal, the trouble is we find particles of the braize. Our experience shows that the fault with the chain grate is too fine grates and under-feed stoker can take care of coarse particles very nicely. On the other hand, wherever braize comes in contact with moving parts or moves over anything you have that terrific abrasive action. Coal plates, 16" plate and over 3/8" only last 4 years on three 1300 h.p. boilers. Moving velocity is not very high, but it gives you some idea of the abrasive action. The small particles burn very nicely, but fines tend to knit together with some grades of coal which are hard to break up. I would appreciate very much hearing some experience on the use of brick for sidewalls rather than water-cooled water box, or for a case where there is no clean water available.

John VanBrunt: As to the use of carborundum brick, its effectiveness is a matter of temperature. Perhaps a very brief description of the manner in which carborundum brick functions may be of interest. Carborundum will prevent adhesion of clinker because of its conductivity, which is greater than that of ordinary firebrick. If the outer end of the carborundum brick can be kept cool enough it should be as effective as a water box. As a suggestion, you might consider a course of short brick along the clinkering line backed up by one or two water tubes that would take the heat from the brick very rapidly and keep the face of the brick cool. I believe results would be as satisfactory as a water box.

The question of size deserves more emphasis. If you consider coke braize screened through a 1" screen you will have particles ranging from say 1" diameter down to 1/16" diameter. The relative masses of these particles are as 1 to 65,000, whereas the relative masses of breeze in which the largest particle is 5/8" are as 1 to 1000. No person would consider buying domestic coal for household use in which the size of the lumps would vary from 1" to 16".

Walter N. Flanagan: If you have enough wind box pressure you won't find it up in the stack.

F. G. Cutler: That is always the trouble, and where you get a condition where you get some coarse braize your fires go out and you don't get ignition.

*Steam Engineer, Ohio Works, Carnegie Steel Co., Youngstown, O.

I would like to ask Mr. Emmons if he ever used by-product gas in connection with coke braize only?

A. E. Blake*: These papers on the utilization of coke breeze, with preceding discussions, tend to show that such material is regarded, generally, as a nuisance and something to be worked off to the best possible advantage, with the least expense.

Our company has been very successful in gasifying such material in connection with the coal gas plants which it constructs, simply by mixing the coke, which is below the 1/2" size with an equal quantity of nut and pea coke, with a resulting mixture of: 25% which passes 1 1/4" screen but not a 7/8"; 25% which passes a 7/8" screen but not a 1/2"; and 50% which passes a 1/2" screen. This is simply a standard specification and can be varied to a considerable degree in practice. The gas which is produced, while generally rated as of low grade, is very satisfactory for firing coal carbonizing retorts and by-product coke ovens. In firing vertical retorts such as our company builds, the producer gas is cleaned while it is hot, by suitable dust catching arrangements, and used at a temperature of 1100 or 1200° F, along with pre-heated air. The normal operating temperature is 2700° F. in the combustion chambers, but at times the temperature has been taken to 3000° F.

For underfiring by-product coke ovens which are heated on the regenerative plan, we cool the producer gas by passing it first through waste heat boilers and then through shower scrubbers, after which it is sent out in light steel mains. You will all recognize the advantage of having producer gas from such a source, from the fact that there is no trouble whatever from tar, as there is when bituminous producer gas is employed. The dust in the gas serves to scour the boiler tubes and keep them clean. The boiler yields a considerable surplus of live steam beyond the requirements of the booster turbine on the send-out line, and also a considerable excess of low pressure steam after the steaming requirements of the producer have been met and all requirements for feed water heat. The lower half of the producer jacket consists of a double walled steel shell, serving as a low pressure boiler. The quantity of steam which comes from this source is just about equal to the demands for steaming the producer. No holder is required in connection with the distribution of this gas because of the means used to synchronize the blasting fans and booster turbines, and control them electrically, so that the "make" of gas depends entirely upon the demand.

Coke producer gas is an ideal fuel for direct fired, low temperature operations such as heating sheet and pair furnaces, annealing furnaces, furnaces for heat treating ordinary steels, and for galvanizing, tinning, wire patenting, lead baths for heating wire, core ovens, mould drying ovens, ladle heating, enameling, and, in short, any operations up to the neighborhood of 2100° F, when possibly a more efficient but more costly gas might prove more economical.

Following are the properties of cooled, clean, producer gas, from coke. These are based upon a recent report of operations from Providence, R. I.:

*Pittsburgh Rep., The U. G. I. Contracting Company, Pittsburgh, Pa.

(a) Chemical Analysis:

CO	30.96%
H_2	9.30
CH_4	0.70
CO_2	3.56
N_2	55.43
O_2	.05

(b) Heating Value —137.6 B.t u. Gross
131.8 B.t.u. Net

(c) Combustion Data:

1 cu. ft, of gas requires 1.0268 cu. ft. air for theoretical combustion.

1 cu. ft. theoretical air-gas mixture contains 67.9 B.t.u.

1 cu. ft. of gas burned with theoretical amount of air gives 1.83 cu. ft. of combustion products.

1 cu. ft. of these combustion products yields as liberated heat 75.3 B.t.u.

(d) This grade of gas is recommended as economical and suitable for direct-fired furnace work at temperatures below 2100° F.

(e) Employment for recuperative or regenerative firing depends upon operation in question, the state of the art, and furnace engineering ability.

These producers which our company uses are in three sizes, namely, 10′6″ diameter, 8′6″ diameter and 7′0″ diameter. The larger size will handle about 45 tons of nut coke a day, or about 35 tons of the mixture which I have referred to.

It has been mentioned that the slagging type of producer for handling coke breeze has not proved much of a success in Europe. From reports I have heard, I should judge that the reason might be due to the fact that only fine coke was employed and the producers stuffed so that the resistance to the blast was too great for rapid operation. We think that some nut coke should be used with the breeze to furnish enough air space or to serve to "open up" the fuel bed.

The breeze portion of the charge generally carries the highest volatile content, the most ash and the most sulphur.

There are seven producers at Rochester, N. Y. Some of them have been running for over eight years, and when I saw them, they were using all the coke, made in the vertical retorts, which would pass a 1″ screen. The ash content of that material was about 23%. There would be no hesitation about making installations to handle material with as high an ash content as 30%.

There is an installation at Providence, R. I., belonging to the Providence Gas Company, which has been in operation for over a year, to furnish producer gas for underfiring a battery of by-product coke ovens. Another installation has just been placed in operation at Bethlehem, Pa., for the same purpose.

E. W. Trexler*: I would like to ask what is considered by the stoker manufacturers and Mr. Emmons as an average life for the front arch alone, and also what is the average life of the two arches, front and rear, combined, that is, what is the comparative life?

H. T. Watts: I would like to ask Mr. Emmons if he will tell us in what way he determines the size of the throat in his double arch construction?

R. L. Ehmann*: I have very little data to offer. The data we do have is so varied, depending on operation in plant itself, it establishes no criterion for anyone contemplating an installation. A large number of our installations have back and front arches and we find, by use of the back and front arches, the life of the arches has been greatly increased. I think, perhaps, to answer specifically the question asked by one of the gentlemen in the meeting regarding life of arches, we might say on front arches burning coke braize with pressure, we have had same in service from 12 to 14 months, back arches last for years. By the use of back and front arches, we have, perhaps, lengthened the life of the front arch, generally speaking, six or seven months.

Louis Ellman†: There is very little that I can add to what has already been said. We do not actually know what the life of the front or rear arch is, as compared to a straight long arch, but, from an engineering standpoint, as Mr. Emmons pointed out, there is no question but that the front arch will last longer if it is shortened and no pressure is carried in the furnace, which can be arranged if a back arch is used. The trouble with long arches has been that all the combustion takes place under the arch. The necessity of carrying a pressure in the furnace has brought about such high temperatures and severe scouring action, that the arch naturally burns up. The thing that is gained by using a front and rear arch, from an arch standpoint, is that the front arch can be shortened and the zone of high temperature is brought between the two arches. Naturally, this will increase the life of the front arch. As far as the back arch is concerned, it will last a considerable time. In the burning of anthracite, which we realize is not entirely comparable with the burning of coke breeze, the rear arch lasts for years. The front arch, also, as far as that is concerned, lasts a long time. I am pretty sure that you can see that from an engineering standpoint, the arch maintenance becomes much less if front and rear arches are used.

If we were able to give actual data on the life of both front and rear arches as applied to coke breeze burning, and as compared to the life of straight, long arches, I would be very glad to give it.

H. W. Brooks‡: At one of the steel plants at Birmingham, Ala., coke braize is being successfully burned in pulverized form. It is understood that under conditions of excess coke braize production this has also been done in one steel plant in Pennsylvania. Under certain price conditions during the war, coke braize has been economically burned in pulverized form in the cement industry. During a visit in Europe last year, I had the opportunity of

*Engr., Bethlehem Steel Corp., Johnstown, Pa.

*District Manager, American Arch Co., 927 Park Building, Pittsburgh, Pa.

†Dist. Manager, M. H. Detrick Co., Empire Bldg., Pittsburgh, Pa.

‡Consulting Engr., Fuller Lehigh Co., Fullerton, Pa.

seeing pulverized coke braize utilized at several plants in the Saar and Ruhr.

As there are many different varieties of coking coals, there are many different kinds of coke braize. Variations in coking conditions also serve to produce braizes of widely varying hardness and abrasiveness. Probably in a majority of cases, it is not economical to burn coke braize in pulverized form. There are, however, cases where certain classes of coke braize are produced in certain quantities and at certain times where the burning of coke braize in pulverized form may be economically justified.

To the operator familiar only with the use of raw coal, two differences characterize the combustion of braize. One equally affects both stoker and pulverized firing, while the other is inherent to pulverized firing only. The former is caused by the absence of sufficient low ignition volatile matter to sustain initial inflammation between the ignition point of the carbon, of the coke, about 850 deg. Fahr. and that of the moist carbon monoxide, about 1200 deg. Fahr., which is substantially the only combustible gas formed during the process of combustion. In bituminous combustion, this 350 deg. gap is progressively bridged in seven stages by the successive ignition of distilled gases, as follows:

Gas	Ignition Range Degrees Fahr.
Acetylene	760 — 820
Propane	900 — 1050
Ethlyene	1000 — 1015
Hydrogen	1075 — 1095
Ethane	1100 — 1300
Carbon Monoxide (Moist)	1190 — 1220
Methane	1200 — 1380

In the combustion of pure carbon, anthracite or coke, radiant heat from specially designed arches and wall constructions must be made available to the flame, and the mixing and turbulent flow of gases must be accomplished, as has been described by Mr. Van Brunt for stoker firing. Otherwise flame propagation ceases between the first stage of ignition of carbon and the second stage of ignition of moist carbon monoxide, and the fire "goes out" either wholly or in part, resulting in excessive losses of unburned combustible in the refuse or ash. That this gap may also be bridged in pulverized fuel combustion is best evidenced by the fact that the method is actually in successful operation in numerous existing installations.

Figures are not immediately available on the Birmingham installation cited, but figures given below will give an idea of the relative ease of starting a furnace of this type by an operator of skill and experience. The Susquehanna Collieries, who burn anthracite in pulverized form, utilize for starting, kerosene in a small auxiliary burner, similar to the design employed by the Bureau of Steam Engineering of the U. S Navy. In seven to nine minutes a coal boiler will sustain inflammation with the expenditure of but 5 to 7 gallons of kerosene, and in 30 to 35 minutes from starting from "cold" the boiler is ready to go on the line. A relatively hot furnace, off say 14 hours, will sustain inflammation within 4 to 5 minutes with the expenditure of but 2 to 3 gallons of kerosene, and such a boiler will be ready to go on the line within ten minutes from starting.

The second difficulty—that of the abrasiveness of coke braize and resultant high pulverizer maintenance—is, of course, inherent only to firing in pulverized form. The Fuller-Lehigh Co. has had considerable experience in pulverizing coke braize for use in foundry facing, paint filler and to some extent for burning. Naturally the plants were limited in size, the largest handling approximately 45 to 50 tons per day. The above installations, however, have given accurate data as to the capacity of the machines, the power required per ton and the cost of repairs on the pulverizers. Mill capacities when grinding coke run from one-half to three-fifths of the capacities on bituminous coal. There is, naturally, considerable difference in the grindability of coke just as there is in coal. By taking the average records, the following figures can be used and considered conservative:

Power—K.W.H. per ton of coke ground, pulverizers, 20 @ $0.01 per K.W.H.	$0.20
Repair material pulverizers @ $0.10 per ton ground	.10
Repair labor pulverizers @ $0.04 per ton ground	.04
Operating labor on entire preparation plant @ $0.30 per ton	.30
Power on drying, elevating, conveying and auxiliary equipment, 3 K.W.H. per ton	.03
Repairs on drying, elevating, conveying, and auxiliary equipment	.02
Operating material as grease, oil, waste, etc	.02
Total	$0.71

To the above must be added the fixed charges and plant overhead which will vary, of course, according to the size of the plant. The above figures are based on a plant of 50 net tons per day, operating on a sixteen-hour basis.

The grinding of coke as well as anthracite coal has been considered by many engineers as costing nearly double as much as bituminous coal, due to the fact that wear and tear on the pulverizers is double that incident to grinding bituminous. On the other hand, the operating labor charges in the plant are little, if any, more per ton. The same number of men will operate a braize plant as are required in a bituminous plant. Initial and operating costs of elevating, conveying and storage amount to the same either for braize or coal. The pulverizing unit alone is the only part of the system which must be increased in size for braize utilization. Correspondingly this necessitates increased power for pulverizing—the increase being of the order of 60 per cent over that required for bituminous pulverization. Decreased drying cost caused by the uniform sizing of the braize, and decreased crushing cost owing to no preliminary crushing being required, both tend to compensate for the higher maintenance cost of the pulverizer. Thus, even though interest and labor charges on the pulverizers may be double those of a bituminous plant, the total increased cost of operation of the system as a whole may be only 15 to 20% higher.

We have hundreds of mills in operation throughout the world grinding cement clinker, which is not only harder and more abrasive than coke, but a great deal larger in size, and on which the specifications for fineness are most rigid. From these many installations we have a very complete record as to operating costs, and these figures are well in line with those given above.

A screen separation mill is the only practicable machine for grinding materials of this nature, for, with an air separation machine, the abrasion on the exhaust fan, piping and cyclone will amount to as much as the repair cost of the grinding elements in the mill proper.

Thus it appears that there are certain conditions which justify firing of coke braize in pulverized form. Few operators can afford to neglect consideration of this in designing or rehabilitating plants. Decision in each case will depend on the character and quantity of coke braize available, the price at which it can be produced and various other factors. With regard to abrasiveness, by mean of tumbler tests, the pulverizer maintenance cost to be expected may be predicted with reasonable certainty. Years of experience have taught the proper line of demarcation between successful and unsuccessful applications of pulverized coke braize firing.

The subject of slagging gas producers has been mentioned by one speaker. During the survey of fuel utilization practices in Europe last year on behalf of the Bureau of Mines, my associate and I tried to find out what was being done there in this connection. We were able to locate but two such installations in nine countries visited. One of these, at Bethune, France, had for a time given satisfactory results, but had been shut down after some six months' operation. The other installation reported near Rome, was finally found to be inoperative, the installation not having proven a success. Thus, the slagging gas producer, while offering most interesting possibilities, has apparently produced no satisfactory results insofar as we were able to ascertain in Europe.

G. C. Emmons: Several points have been brought out relative to the use of carborundum brick in connection with forced draft chain grates. Our experience with this material on underfed stokers might be interesting.

We found when using fire brick that a large hole quickly developed immediately above our tuyere boxes. Due to its higher fusion point and greater ability to withstand abrasion we then employed carborundum brick at this point. This proved very satisfactory when burning only bituminous coal, but as soon as we mixed with this fuel, coke braize obtained by rescreening our furnace coke at the blast furnace, we were surprised to find that carborundum brick did not last as long as fire brick. This was due to the iron ore contained in this fine coke reacting with the carborundum. By substituting alundum brick for carborundum, we have been able to hold this wall very satisfactorily.

One phase that has not been touched on is the relationship of the length of the stoker. I think it is possible, perhaps, to get a stoker too long for burning coke braize. There is an installation going into the Pittsburgh district now which I believe is 30 feet in length, which, as far as I know, is the largest stoker proposed for that service. That may be too long; I do not know, but it is quite important to have the length of the stoker very generous. We should not be governed too strongly by the ability of a stoker to burn a certain number of pounds of fuel per square foot per hour. We should choose a narrow, high boiler and then make our stoker just about the same width as furnace setting, and then make our stoker at least 18'6" long. I think if this dimension is exceeded somewhat you will get even better performance, for you will have a lower ash pit loss.

Relative to the use of by-product coke oven gas, which Mr. Cutler asked about, we have used by-product coke oven gas principally to maintain ignition, and the way we do is not a very good way, but probably the way we all use it. We run by-product gas pipes into the furnace and turn on the gas, with the result that we punish the arches terribly. I have a slide which I did not show, which shows a combination setting for blast furnace gas and coke braize stokers where the combustion chambers are entirely separate and I would be very glad to let you look at it later, because, for best results, I think we should employ some similar arrangement when burning these two fuels on the same boiler.

I wish to emphasize that with a double arch setting we have proved that without any positive pressure under our arches we can obtain satisfactory ignition even when the volatile goes down to less than one per cent, whereas with a single arch setting under these same conditions, you either have to carry positive pressure under the arch or employ coke oven gas.

Answering Mr. Watts' question—our practice in that work showed that we had used 32 developed horse power per square foot of throat opening. With the temperatures encountered in the furnace, this gives a velocity in the throat of 24 feet per second. If this velocity is much exceeded, a great deal of fine ash will be driven through the throat and be deposited on tubes.

The location of the throat is likewise of considerable importance. Some designs show the throat in straight tube boiler settings starting right at the front of the boiler even when an inclined baffle is employed. In this construction, the gas, I am sure, does not fill the first pass. Due to the inclination of the baffle, the throat should be located about the center of the first pass or very slightly forward of the center of the first pass. The conclusion may possibly have been reached that the use of double arches is more applicable to straight tube boilers than curved. I hope you have not come to that conclusion, for it is not the fact. Just recently I designed a front and rear arch furnace, and we have made two layouts, one for straight tube and the other for curved tube boilers, using identically the safe furnace. With the straight tube boiler the front header was located 15 ft. above the floor, and in the case of the curved tube boiler the mud drum was located 12 ft. above the floor.

Concerning the relative life of the arches of the front and rear arch design and the front arch furnace, we have no good comparison, for with the front arch settings we have punished the arches in two ways, one by the use of coke oven gas, and the other by the use of positive pressure. We have not had an opportunity to employ both under the same conditions, namely, negative pressure, on account of the inability of front arch settings to maintain ignition with negative pressure on low volatile braize.

Combustion Control By Machinery*

By C. H. SMOOT†

THE control of combustion by machinery involves the use of regulators which are controlling machines.

Their function is to supply fuel and air in proper proportions—first, to each other, and second, in proportion to the requirements.

The equivalent of these regulating machines are at present in almost every installation of combustion apparatus, such as pressure regulators for fans, stoker speed or gas pressure regulators for gas.

The difference between combustion control and merely regulating the speed of a stoker engine and pressure of fan is comparatively small in apparatus, but great in principle.

Combustion control is the use of machines such as regulators to regulate for a chemical mixture. In other words, to supply gas and air in relative proportions, which produce a suitable chemical mixture for maximum combustion efficiency—that is, a quantity of air just sufficient to completely consume and combine with the combustible element of the gas. If this quantity is greater or smaller, part of the heat energy is wasted, either as sensible heat carried away by excess air or as incompletely burned combustible which carries away potential heat values.

With gas, oil and powdered fuel, which are burned in a very short space of time, the momentary input of air and fuel must be regulated moment by moment to exactly correspond to the degree of combustion sought.

Solid fuels in a stoker carry on for a certain length of time and the physical characteristics of the fuel bed tend to maintain a uniform combustion for considerable periods, even though the momentary supply in fuel and air is for the moment out of proportion.

In adapting mechanical regulators to the combustion of solid fuels, it is a comparatively simple matter to regulate the fuel input moment by moment in proportion to the air input and thus insure that at any time the total amount of fuel and the total amount of air which has been supplied—say during the preceding half hour— are accurately in proportion, both moment by moment as well as hour by hour.

In order to insure that the hour by hour equality between fuel and air supplies is correct, a moment by moment regulator is the most satisfactory answer.

It is easy to make a regulator which controls the rate of fuel supply. It is, however, difficult to make a regulator which would integrate the fuel supply for a considerable period and at long intervals adjust the rate of fuel to balance off against the air.

The broad problem of combustion control involves a thorough study of regulation in itself. All of the regulating problems which have confronted the designers of prime movers—engines, turbines and the like—have their bearing on the combustion control job. The stabilizing of such regulating equipment, so that it will be accurate and at the same time not oscillate from either side of its proper position is a very extensive study in itself.

Each different job, each different plant, has special phases of the regulating problem to be considered.

In order to make combustion control uniformly possible, it is necessary to have a regulating mechanism which is powerful, sensitive, stable and accurate, and these specifications must be met by regulators, governing the speeds of motors to give accurate regulation of rpm, governing the speeds of steam engines and turbines, to give pressures delivered by fans; controlling dampers for pressure and pressure differentials, etc.

Sometimes the regulator is called on to regulate accurately pressure and pressure differentials to within an error of .001" water column and right alongside a regulator is called on to govern the steam pressure of a plant running into hundreds of pounds to within a few pounds limit.

Combustion control is not a matter of isolated apparatus. To be successful it is a comprehensive system. To insure its effectiveness in plant operation it mut be interlinked with the man-organization in an entirely practical and everyday working manner. It is not feasible to use combustion control apparatus for the purpose of eliminating the human element. Reasonable control apparatus must be planned from the ground up, having as its objective to assist the human element in the task of operating their plants, rather than to replace.

For this reason the most successful combustion control installations are installed with centralized, bench board type of control and return signal, so that at some point in the plant a man, whether he be load dispatcher, or combustion engineer, has at his finger tips the adjustment and manipulation of all quantities entering into the combustion problem

The regulator, to be useful in any section of the combustion control job, must be a complete regulator, in which cause and effect are balanced, just as in a speed governor the speed of rotation is balanced by the manually adjusted counterweight or spring, in which the speed desired at the machine is only produced when the two forces are equal and opposite and the governor remains at rest.

To regulate the speed of an engine, the amount of steam admitted must be varied with the load, more load calling for more steam, and a different position of valve and governor follows every change in rate, but the balance between centrifugal force due to the speed and loading due to counterweight or spring tension is always satisfied or the governor takes a new position to produce this balance before it comes to rest.

The electric motor supplying fuel to a boiler is in exactly the same case. A given position of the

*Presented at Fuel Savings Conference May 13-14, 1925

†President, Smoot Engineering Corporation, New York, N. Y.

motor controller does not mean a given speed of motor, as the motor speed is dependent on many other factors than position of rheostat alone. It has been found as a matter of experience that to get reasonable control of a variable motor speed in a control system that a speed governor mechanism is necessary, just as if the controller were a throttle valve. The speed governor shifts the controller until the produced speed satisfies the requirements of balance between speed governor and loading device.

Figure number one represents graphically this condition and illustrates the results of tests made in a Western plant, in which the notch position of the rheostat is plotted against the speed of the chain grates driven by the motors. The complete unreliability of the so called "position regulators" is shown by the fact that a 2 to 1 variation in speed has been found to correspond to the same contact point of the controller.

In the control of a flow of air or gas, the same considerations apply.

There are two elements—one a measure of the actual volume flowing and the other a quantity assigned to the regulator which determines the volume for which the regulator is in balance.

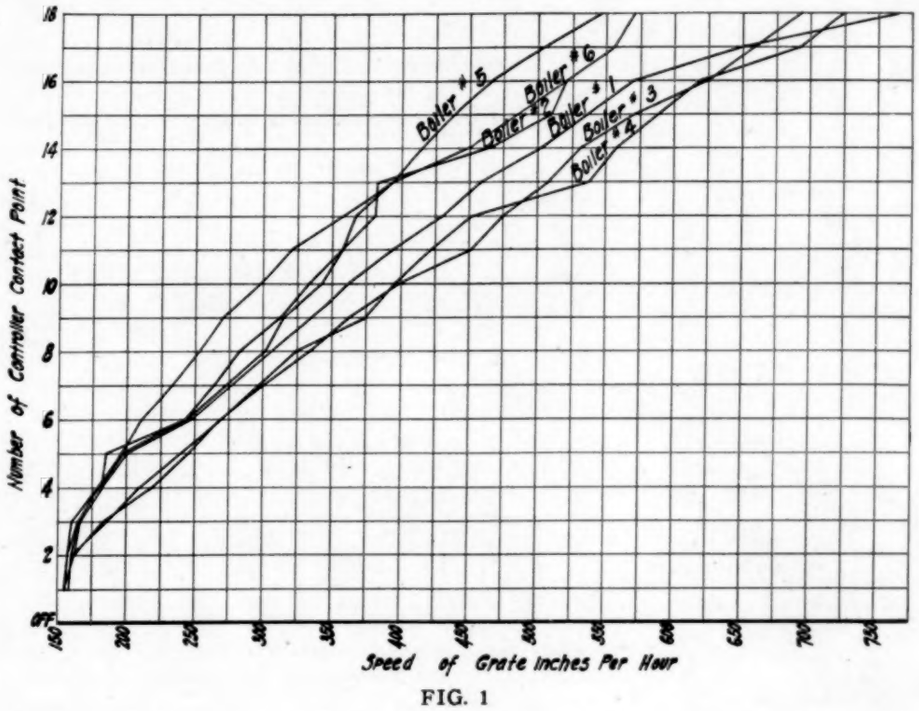


FIG. 1

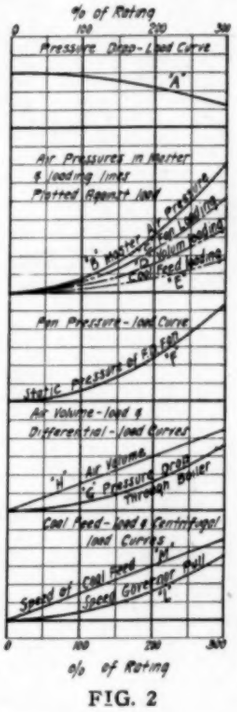

% of Rating
Pressure Drop-Load Curve
"A"
Air Pressures in Master & Loading Lines Plotted Against Load
Fan Pressure-Load Curve
Static Pressure of F.D. Fan
Air Volume-Load & Differential-Load Curves
Air Volume
Pressure Drop Through Boiler
Coal Feed-Load & Centrifugal Load Curves
Speed of Coal Feed
Speed Governor Pull
% of Rating

FIG. 2

The gas and air volume regulators are just like speed governors. They are called on to move the valve or some other mechanism which will vary the suuply of gas or air until a flow meter type measurement of the quantity actually passing is balanced by the counterpoised loading placed on the volume regulator.

With such an equipment the volume remains constant, just so long as the counterpoised loading remains constant. The function of the regulator is, therefore, to compensate for variations of pressure or resistance in the air circuit in such a way that the volume flowing is always maintained equal to the volume called for by the adjustment of the regulator.

A combustion control system is a group of such regulators, all acting in unison, one controlling a given fuel supply, another an air supply, a third an air pressure, a fourth an induced draft fan, a fifth excess boiler feed water pressure, etc. Each one of these individual elements is an essential input quantity to produce the net result.

For each condition there is a fixed ratio between all of these different inputs.

The system of combustion control which we are considering synchronizes these different elements through a master controller.

The master controller is a pace setter, which supplies counterpoise loading to all of the regulators. The regulators in turn balance the counterpoise loading by the produced result, whether it be speed of stoker, volume of gas or volume of air.

In this system the position of the controlled element is not a factor. Whatever position of damper, rheostat or throttle valve is necessary to give the result called for by the master is found by the regulator, as the regulator continues to function until balance is obtained between loading and produced result.

Figure number two illustrates in a schematic way the basic thought of the Master Controller, how the impulses of the steam pressure are converted into and balanced by Master air pressures, which are sent to the individual regulators as loading pressures. These loading impulses are balanced against the desired results in each regulator and a fixed ratio of fuel to air quantitity is obtained independently of the rating as the lines "H" and "M" clearly show.

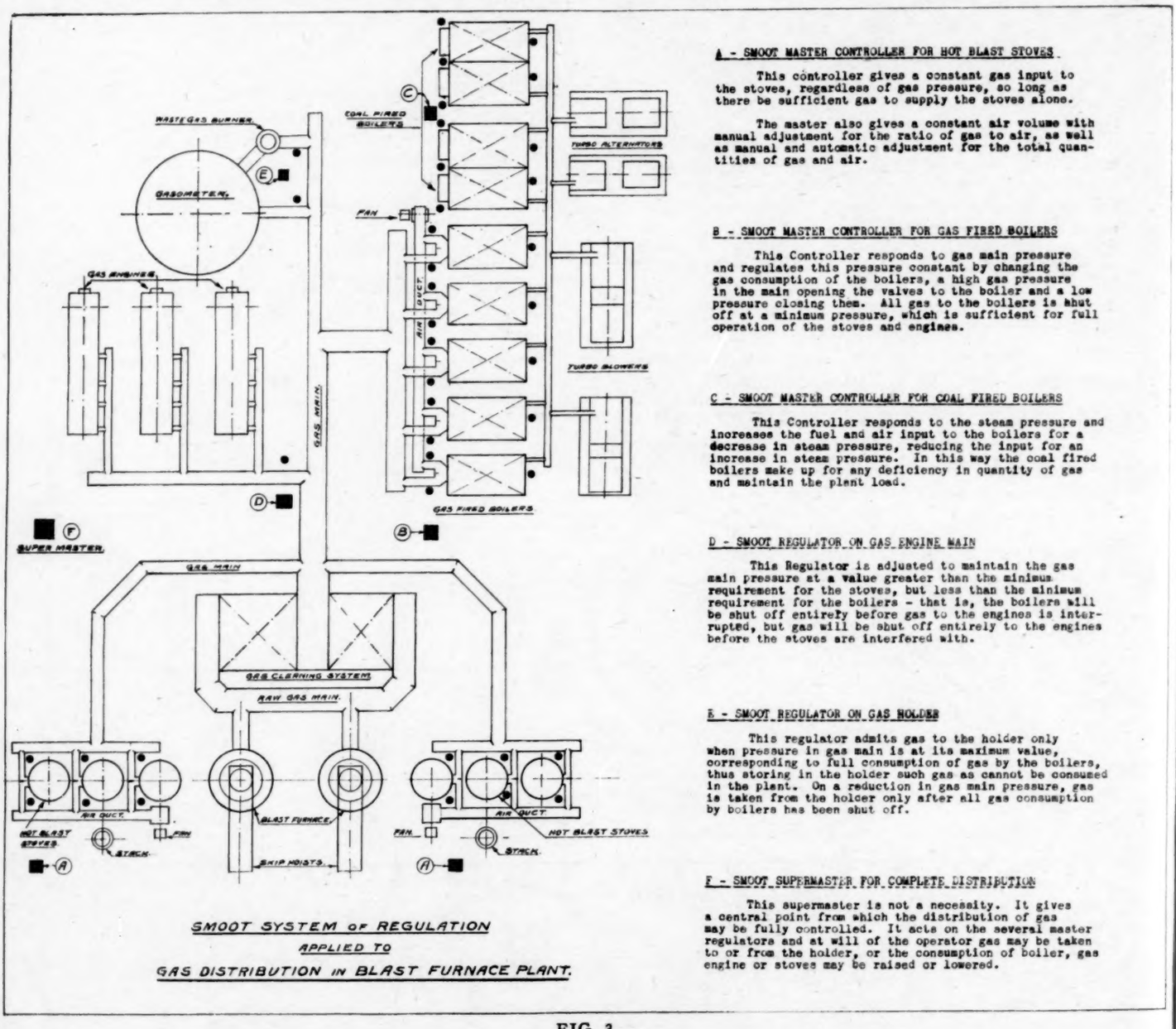
Combustion control by machinery is useful or advantageous to a plant, because a greater degree of momentary accuracy is obtained by the use of ma-

chines adjusting valve, etc., than by the use of men doing the same things.

There is no problem of combustion control which has been solved which cannot also be accomplished by the use of a man to manipulate a valve, or the like, and theoretically, if a man be stationed at each of the points of adjustment throughout the system previously described, he could so adjust his valves

justment of all valves, one adjustment being to maintain the relative volumes of gas and air indicated by their meters, the other to adjust both valves simultaneously, preserving the relative volumes, but changing the total volumes so as to maintain a given gas pressure in the main.

If they fail in making either adjustment correctly, they would lower the efficiency of the combustion,



SMOOT SYSTEM OF REGULATION
APPLIED TO
GAS DISTRIBUTION IN BLAST FURNACE PLANT.

A - SMOOT MASTER CONTROLLER FOR HOT BLAST STOVES

This controller gives a constant gas input to the stoves, regardless of gas pressure, so long as there be sufficient gas to supply the stoves alone.

The master also gives a constant air volume with manual adjustment for the ratio of gas to air, as well as manual and automatic adjustment for the total quantities of gas and air.

B - SMOOT MASTER CONTROLLER FOR GAS FIRED BOILERS

This Controller responds to gas main pressure and regulates this pressure constant by changing the gas consumption of the boilers, a high gas pressure in the main opening the valves to the boiler and a low pressure closing them. All gas to the boilers is shut off at a minimum pressure, which is sufficient for full operation of the stoves and engines.

C - SMOOT MASTER CONTROLLER FOR COAL FIRED BOILERS

This Controller responds to the steam pressure and increases the fuel and air input to the boilers for a decrease in steam pressure, reducing the input for an increase in steam pressure. In this way the coal fired boilers make up for any deficiency in quantity of gas and maintain the plant load.

D - SMOOT REGULATOR ON GAS ENGINE MAIN

This Regulator is adjusted to maintain the gas main pressure at a value greater than the minimum requirement for the stoves, but less than the minimum requirement for the boilers - that is, the boilers will be shut off entirely before gas to the engines is interrupted, but gas will be shut off entirely to the engines before the stoves are interfered with.

E - SMOOT REGULATOR ON GAS HOLDER

This regulator admits gas to the holder only when pressure in gas main is at its maximum value, corresponding to full consumption of gas by the boilers, thus storing in the holder such gas as cannot be consumed in the plant. On a reduction in gas main pressure, gas is taken from the holder only after all gas consumption by boilers has been shut off.

F - SMOOT SUPERMASTER FOR COMPLETE DISTRIBUTION

This supermaster is not a necessity. It gives a central point from which the distribution of gas may be fully controlled. It acts on the several master regulators and at will of the operator gas may be taken to or from the holder, or the consumption of boiler, gas engine or stoves may be raised or lowered.

FIG. 3

and read his flow meters as to follow all the changes and maintain constant the condition he has been assigned to maintain constant.

To do this manually with accuracy would require for each man a complete set of accurate instruments, whose readings would tell him what to do in order to balance cause and effect.

The boiler plant men would have to watch their gas pressure and their air pressure, their gas flow meter and air flow meter, and make a double adwasting gas, or would interfere with the operation of the stoves or boilers by taking too much gas.

At the stoves the manual adjustment for gas quantity would have to vary for variation in pressure and the valve would have to be continuously manipulated to maintain a constant volume of gas entering the stove.

Likewise, frequent manipulations of the air valve would be necessary to maintain a constant volume of air suitable to completely burn the admitted gas.

All of these men may be replaced by machines, which will carry on from time to time the simple job of maintaining a balance between cause and effect through the adjustment of a valve.

Combustion control by machinery is the substitution of an accurate regulator for a man in this respect.

The regulator which is not subject to fatigue or lack of interest is always on the job; and when a comprehensive system is developed, which does not require more attention than any other piece of mechanism, it is amply able to produce, will turn out a better job of regulation than it is possible for a crew to do. Furthermore, this better job will be done at vaster less expense than if done manually.

The co-ordination of a number of such regulating elements, such as occur in the boiler plant, cannot be duplicated by men, as it would require a number of men regulating each a boiler, and a larger crew to make the same adjustments on all boilers. In this respect the system we have described is very materially ahead of the theoretically possible man organization possible to accomplish the same result.

The proper connection of the human element to this system is at the master and super-master controllers. Here it is possible for one man to supervise the work done by a large number of regulating machines and to get the entire plant under one man control.

The man stationed at the master controller can make any adjustment called for by the existing circumstances in the plant operation and all of the valves, dampers, etc., each of which contribute their share of the gross result, are mechanically operated by the local regulator to produce the result which the man at the central master desires.

Furthermore, the combination of master controller and regulators will execute for an indefinite period the wishes of the operator as expressed by his adjustment at the master.

From experience in steam boiler plants, this is a very essential matter and the entire system of control is built around the single idea of giving a man mechanical apparatus which will execute the orders of the man at the central control point.

In steel mills there is a very pretty problem in combustion control, where blast furnace gas is used in conjunction with solid fuel for the generation of steam, heating stoves and operation of gas engines.

There is a much bigger problem involved than merely the proportionate quantities of gas and air. The distribution of the gas in order of preference—first, to stoves and last to boilers—is distinctly a function of the combustion control system.

Figure number three represents a diagrammatic outline of a complete blast furnace gas control and distribution system.

Fundamentally, the arrangement of the apparatus shown here is to give priority of distribution of gas to those appliances needed most, and second, to guarantee an economical use of the gas so distributed.

The pressure of the gas in a blast furnace main is regulated indirectly by the amount of gas consumed in the boiler plant. A higher pressure in the gas main acting through the master controller results in a greater consumption of gas by the boilers, so that as the pressure progressively increases, the quantity of gas follows suit, with the result that a comparatively narrow difference between maximum and minimum gas pressure is maintained.

By the time the gas pressure has reached its maximum value the boiler is consuming the maximum amount of gas. On the other hand, as the gas supply decreases, the pressure in the gas main is maintained by a corresponding closure of the gas flow to the boilers, with finally a complete shut-off of gas to boilers at a pressure of —say—6″ to 8″ water column in the gas main. Thus, before the pressure in gas main falls to nothing, the consumption of gas by the boilers is entirely stopped.

At the stoves a different scheme is employed. The quantity of gas admitted to each stove is held constant by a constant volume regulator. Likewise the air taken by the stove is controlled by another independent constant volume regulator.

The quantity of air and the quantity of gas passed by these regulators is manually adjusted by the master controller and when set by the heater remains constant regardless of gas or air pressure. Any increase of pressure in either gas or air tends to send a greater volume to the stove, which reacts on the flow meter orifice, making a greater pressure difference, which in turn acts on the regulator to produce a closure of the valve and the reduction of the volume back to its previous value, the valve being more closed than before, but passing the same volume as originally. Of course similar devices can be readily applied to natural draft conditions.

The minimum gas pressure, at which the consumption of gas is interrupted by the master controller of the boilers, is maintained sufficiently high to keep the gas volume regulators at the stoves within range and passing the full normal volume of gas to the stoves necessary for the blast furnace.

This arrangement avoids waste of gas through the stove; because of high pressure, insures a uniform heating from time to time, as it maintains a constant volume of gas to the stoves, and provides a very simple central point whereby the combustion for efficient heating is accurately adjusted and inherently maintained at whatever adjustment has been made.

At the stoves, as well as at the boilers, the master controller provides a double element of adjustment, one element being the ratio, or relative quantities of gas and air, the other being the total quantities of both gas and air.

At the stoves the adjustment of total quantity, as well as the adjustment of ratio, is maintained purely manually within the ordinary working conditions.

In Figure number four is shown a diagrammatic outline of simplified combustion control applied to the hot blast stove.

There is an entirely independent air volume regulator and gas volume regulator. The counterpoise of these regulators is obtained from air pressure derived from the master control element. This is a very simple form of air pressure reducing valve, which regulates to maintain a constant, but readily

adjustable air pressure on the counterpoise elements of both regulators.

The increase or decrease of either gas or air volume in proportion to the other is permanently adjusted through the bleeder screws, this adjustment being only for relative volumes.

The adjustment of total quantities is made through the adjusting screw and spring loader, and

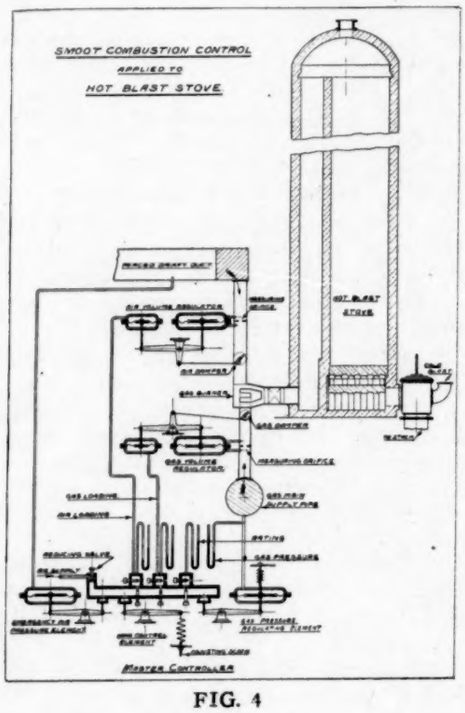


FIG. 4

acts to vary the total pressure in the master. The master is so arranged that all the individual loading pressures derived from it maintain a fixed ratio to each other, but rise and fall proportionately with the load pressure in the master controller, thus the master inherently provides two independent adjustments which do not react one on the other; the one for relative volumes, and entirely independently, and without disturbing relative volumes, the other controls the total quantities.

In the operation of the stove the rate of heating is determined by the total volumes of air and gas supplied. This is adjusted as found suitable in plant operation and when so adjusted is kept constant by the regulating apparatus, this producing equal temperature for heat after heat.

A change in character of gas calling for a different mixture or different character of gas calling for a different relative quantity of gas and air, is corrected by a single adjustment of a gas volume regulator, and an analysis with an Orsat is probably the best means for a proper setting of these relative volumes.

Certain safety precautions are advisable in the stove heating matter and the emergency air pressure element is provided for the purpose of cutting off or reducing the master air pressure in case the pressure of forced draft goes below a certain minimum safe value, and in case the forced draft pressure goes to zero the master loading pressure also goes to zero, which closes both gas and air dampers. Likewise if the gas pressure should fall or go below the minimum value for normal heating of the stoves, the emergency gas pressure element will reduce the master loading pressure progressively, cutting down the volumes of air and gas supplied to the burners proportionately and progressively, until finally for zero gas pressure there will be zero master loading pressure and both air and gas volume regulating dampers will be closed.

Thus, an accidental failure in either gas or air supply through its action on the master will readjust this master for an abnormally low quantity of heat input and close off the supply of both gas and air. This is a progressive matter and not an absolute interruption, for as the gas pressure is reduced below normal minimum value, the master controller on the stove reduces the gas volume supplied to the stove just a sufficient amount to maintain the gas pressure at an appreciable value, thus a reduction in gas presure causes a slowing down of rate of heat of stoves, but still a uniform rate of heat is maintained, the gas is evenly distributed among the different stoves under heat and the quantity of air is as before kept in proper relation to the quantity of gas.

You will be interested to note that throughout this arrangement nowhere does the volume of gas or air act against the other. There is no balance between gas volume and air volume, but merely the use of two constant volume controllers, one on gas

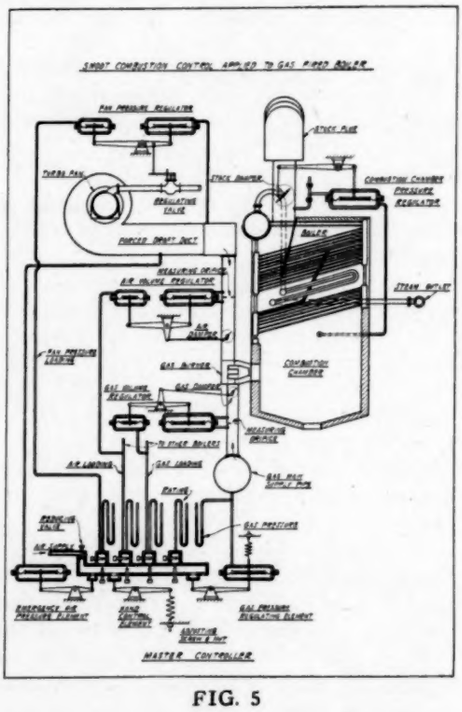


FIG. 5

and the other on air, and each of these volume controllers is assigned its proper place or quantity by the master controller, which acts alike or proportionately on each of the volume regulators, but in no wise transmits the volume input from one to the other.

Where the complete gas distribution scheme is called for, a remote adjustment of the stove heat-

ing master regulator is obtained through remote adjustment of the hand-controlled element through auxiliary air pressure and by this means the amount of gas and air taken by the stoves is simultaneously increased or decreased at a distant point, where there is in use the super-master regulation for the purpose of governing the distribution of gas throughout the plant.

The arrangement of control for gas fired boilers shown in Fig. number five is practically identical to that shown for the stoves, except that the gas pressure element is always active and the gas pressure is used to control the volume of gas and air admitted to the boiler and varies with this pressure. The hand control element is a maximum limit device, which has the effect of controlling definitely, to a maximum value, the quantity of gas and air consumed by the boilers. The air pressure element becomes an emergency device as before and acts to reduce the quantity of gas and air consumed by the boiler in case the forced draft fan accidentally shuts down or is inadequate to supply the necessary quantity of air to completely consume the amount of gas entering the boiler.

The adjustment of the air pressure controller element is so made that all of the gas and air is shut off from the gas burners in the boilers when the gas pressure in the main reaches a definite minimum value, such as 5″ or 6″ pressure, thus saving the gas in this period of deficiency for consumption at the stoves, where it is usually more needed.

As the gas pressure increases, it acts on the master controller, which in turn calls for greater volumes of gas and air to the different burners and by consuming more and more gas retards the increase in pressure of gas supply until the boilers are taking all of the gas which the burners will pass.

Where a super-master, F of Fig. No. 3, is employed for controlling the distribution of gas throughout the entire plant, an additional master controlling element is employed so that by air pressure from the central point the action of the gas main supply pressure may be varied to give more or less gas consumption to the boilers in a manner entirely similar to the remote control method employed by the stokers; thus from a central point, if thought desirable by the gas distribution man, the stove consumption of gas might be reduced for a short time in order that the steam load be carried, by increasing the gas consumption at the boilers, which temporary condition would later be altered and the normal distribution re-assigned to the plant from the super master control panel.

If gas engines are also operating on the system, similar control may be installed on the branch from the gas main to the gas engine house, which through adjusting the pressure of gas reaching the gas engine room would in a large degree control the distribution of gas through this part of the plant.

Similarly, indicators may be used which will give the man in the gas engine room complete information on the gas distribution condition and allow them to adjust their gas engine loading accordingly.

In the boiler house there are usually a certain number of boilers under coal fire. They are necessary to make up for a deficiency in quantity of gas for the steam requirements.

In the system shown in Fig. No. 3, these boilers are indicated as governed with a steam pressure master controller, which is identical to the combustion control system used in boiler plants, whether they be gas fired boilers or not.

At this point of control the steam pressure is the guiding element, a low steam pressure acting to give a high master loading pressure, which in turn adjusts for a greater rate of fuel feed and a greater air volume to each of the boilers.

A deficiency of gas from the blast furnaces reduces the amount of heat generated in these boilers, indicated by a slight reduction in steam pressure, which through its action on the coal fired master correspondingly increases the rate of coal combustion by an amount just sufficient to maintain the steam pressure within the working range.

Thus the coal fired boilers are controlled to pick up the load as it is dropped by the gas fired boilers.

On the coal fired boilers similar methods of combustion control are employed and the master regulator assigns to each boiler a proper and proportionate fuel and air input to produce maximum fuel economy.

It is apparent that such a comprehensive system of co-ordinated control would create the highest economy in utilization of the gas B. T. U. and coal energy and materially reduce production cost of the plant.

---

*Combustion Control**

By T. A. PEEBLES†

DURING the past ten years rapid strides have been made in the application of automatic equipment to the control of combustion in boiler furnaces. For a time engineers were inclined to make no distinction between a real system of combustion control and a device whose only function was to maintain a substantially uniform steam pressure, and they knew from experience that uniformity of steam pressure was no indication of economy of combustion. In fact some devices for maintaining constant pressure often did so at the expense of economy. However, when the various factors affecting economical combustion were taken into account in the design of combustion control system, the results secured exceeded the expectations of both the purchasers and the manufacturers. It soon became apparent that the difference between the test

*Presented at Fuel Savings Conference, May 13-14, 1925.

†Chief Engineer, Hagan Corporation, Pittsburgh, Pa.

efficiencies and monthly operating efficiencies need not be nearly so large as usually existed, and in numerous instances the monthly operating results closely approached test results and often exceeded the guarantees on which boilers and fuel burning equipment had been purchased.

In addition to the reduced fuel consumption, there resulted a general improvement in operating conditions, lower maintenance on brick work and metal parts within the furnace, and greatly reduced the amount of work the fireman had to do. This made possible much closer supervision of the fires and enabled the fireman to do much more effectively than he had done in the past, those things which must be left to manual control. It is now generally recognized by engineers that they cannot afford to have firemen adjusting boiler dampers, changing the speed of fans and stokers, and work of this nature, because it can be much better done mechanically and at the same time the fireman's time and attention are not taken from the more important work he should do.

The savings effected when expressed in terms of the cost of combustion control equipment are sometimes hard to believe. However, combustion control equipment represents a very small fraction of the cost of a boiler plant while the cost of fuel burned per year, may eual or even exceed the first cost of the entire plant. There are many cases where combustion control equipment pays for itself in fuel saving at the rate of ten or twelve times per year, and two or three times per year is about the minimum.

While it is recognized that the combustion of fuel in a metallurgical furnace is a different problem from that encountered in a boiler furnace, the two have so much in common that it seems wise to at least consider the application to metallurgical furnaces of equipment similar to that which has shown such improvement in the operation of boiler furnaces. In the operation of a boiler furnace, the ideal condition would be complete combustion with the theoretical air supply, but since this cannot be secured, a departure from ideal conditions is necessary. Since the primary consideration is the greatest possible economy in the use of fuel, the departure from theoretical conditions is the one which will still make it possible to most closely approach the ideal results. This is secured by admitting excess air in just sufficient amounts to insure complete combustion. The actual amount required will vary with the kind of fuel being burned, the character of the fuel burning equipment, and the nature of the load to be handled, but for each given installation there is a certain percentage of excess air which will give the best results, and this is found to be the percentage which is necessary to insure complete combustion. When the desirable amount of excess air has been determined, combustion control equipment is adjusted to maintain this condition and it is done with surprising reliability and accuracy.

Figure 1 is a chart taken from a CO_2 recorder on a boiler burning blast furnace gas, and shows how closely the air can be regulated to the varying gas flow by simple automatic equipment. Check samples with the Orsaat apparatus show about 25 per cent CO_2, .5 per cent oxygen, and no CO.

In the combustion of fuel in various types of metallurgical furnaces, best results would also be secured with perfect combustion using the theoretical air supply. In some metallurgical furnaces, the presence of excess air is not objectionable and the control problem would, therefore, not differ greatly from that encountered in the operation of a boiler furnace. The minimum amount of excess

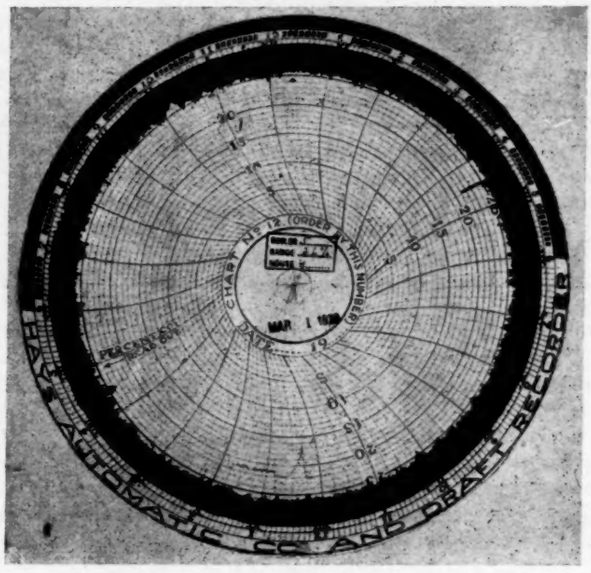


FIG. 1

air required to give complete combustion could be determined and the control equipment set to maintain this condition of best economy. In other metallurgical operations it is important that no excess air be present because of the loss of material that would result from oxidation. In such cases the operation is carried on with a deficiency of air. This deficiency is made just as small as is necessary to insure that there will not be periods of excess air supply. The loss resulting from incomplete combustion is considerably greater than the loss that would result from excess air if it were possible to operate as a boiler furnace is operated, but this loss is small compared with the loss of material to be heated, and the greatest overall economy results when no excess air is permitted to enter the heating chamber. Automatic control equipment which can be adjusted to maintain a given amount of excess air can also be adjusted to maintain the desired deficiency of air, and there is every reason to expect the same uniformity of operating conditions and improved overall results that are being secured in many boiler furnaces.

The application of an ideal system of combustion control is often rendered difficult in boiler plants on account of the nature of auxiliary equipment to be controlled. All stokers are not equipped with convenient speed changing devices, and in some cases, stoker and fan drives are selected for their low first cost or economy of operation rather than from the standpoint of their adaptability to accurate speed control over the necessary range of operation. The application of control equipment to metallurgical

furnaces will proceed much more rapidly and will give better overall results if the engineers in charge of such installations will provide auxiliary equipment which is best adapted to function with automatic control equipment. The manufacturers of the control equipment have had experience with auxiliary equipment that is satisfactory and their advice can safely be followed.

*Automatic Combustion Control**

By E. G. BAILEY†

IN past years stokers and coal-burning equipment have been guaranteed, sold and approved on the basis of tests usually of only a few hours' duration. These tests were made under the most favorable conditions with the manufacturer present to direct or, perhaps, operate the equipment, and the greatest care was taken to watch the readings of all test instruments and make every needed adjustment to keep the equipment operating under the most favorable conditions. After the tests were completed and the guarantees met, as they usually were under such expert operation, the instruments were promptly and carefully removed and the equipment turned over to the regular plant operators. Even though the firemen and plant operators did their best to run the equipment properly, the every-day results usually fell far below the test results and this was taken as a matter of course.

The development of meters and recording instruments has done much to change this, by giving the every-day operator an equal chance with the test operator to see continuously the results as they are being obtained with the opportunity to improve and maintain them. Even with the aid of such instruments, test results cannot always be duplicated and maintained, because of the time and attention required to properly adjust and operate the stoker or other such equipment. The alternative is to give a man fewer boilers to look after, so that he can more frequently make the adjustments or do the supplemental work needed, but the economic law of the survival of the fittest is rapidly eliminating the inefficient equipment as well as that which is efficient only through high cost of labor and constant attendance. To offset these higher labor costs and the fallibility of hand operation there is a rapidly growing demand for equipment to automatically control the combustion processes. This is certainly a step in the right direction, but the time has not yet come when the best possible results can be obtained from such automatic control due largely to the limitations in the stoker and pulverized coal-burning equipment which is to be controlled.

Coal-burning equipment has passed and is still passing through a very interesting evolution. Hand firing has almost entirely given way to the mechanical stoker, and those stokers requiring the most attention and labor are rapidly being superseded by those more responsive to control, with the final goal a coal-burning equipment which will respond to changing only the stoker or feeder speed and the rate of air supply, and thereby maintain proper fuel and air distribution which is necessary for high combustion efficiency.

All three of the more popular methods of burning coal at the present time, viz., forced draft, chain-grate stoker, underfeed stoker and pulverized coal euipment, may prevail for some time, but the final outcome will depend largely upon the success of the manufacturers to develop their respective equipment to give flexibility and accuracy of control, whether by hand or automatic means. Perhap all three methods of burning coal will continue for many years, the selection being determined on a basis of character and quality of fuel available and the load conditions to be met.

All boiler plants have load changes to meet and variations in quality of coal to contend with, but all of the present fuel-burning equipment is not equally responsive in meeting these changing conditions with the highest efficiency.

Automatic control is sometimes looked upon and sometimes claimed as the remedy for all of the shortcomings and imperfections of the present methods of burning fuel. This, however, is not the case, and while there may have been some backwardness in developing complete and thorough automatic control, it cannot proceed faster than the development of the equipment which is to be controlled.

The manufacturers of stokers and pulverized coal-burning equipment must develop and improve their product so that it can be made responsive to automatic control devices that have already been developed, and the final test of the best coal-burning equipment will be as to whether or not it responds satisfactorily to automatic control. If it can be made to do so, then automatic control may not be as necessary as it is now thought to be, for stoker or coal-burning equipment that is readily controlled by automatic means is also more easily controlled by hand and with much less time and labor than is required to manipulate some of the coal-burning equipment that is installed in the plants today. The saving in labor and the elimination of the human element will no doubt favor automatic control, especially for variable load conditions.

It seems that manufacturers of some of the coal burning equipment have tried to remedy their shortcomings by adding more adjustments to both air and fuel supply, so that these may be varied in different parts of the furnace and fuel bed. This, however, is departing from the final goal which will be (1) a fuel burning equipment that responds to a minimum number of control factors, and (2) capable of readily obtaining any desired capacity within the limits of the equipment, and (3) always maintaining the best efficiency.

*Presented at Fuel Savings Conference, May 13-14, 1925.

†Pres. Bailey Meter Co., Cleveland, Ohio.

Let us for a moment consider the specifications of the fuel-burning equipment we would like to have in our plant. As the load changes the pressure tends to vary inversely, and this variation should immediately change the rate of heat supply to the boiler furnace and thereby meet the load requirements. In a furnace burning coal with forced draft, there are a minimum of three things to be changed; rate of fuel supply, air supply and rate of escaping gases. These should all be made simultaneously from the steam pressure, especially in the case of fuels burned in suspension. The total air supply should be readily readjustable to suit the efficiency conditions, maintaining the desired excess air at different ratings. The forced draft supply should also be readily readjustable to maintain the proper furnace draft at different ratings. So, if we had variable speed drive of sufficiently wide range to cover the entire load changes, and if the air distribution to the furnace and the coal distribution and mixture with the air, were all worked out in the stoker or pulverized fuel equipment design, then these three speeds would be all that need be controlled. The guiding factors for such control should be steam pressure for capacity, excess air measurement for efficiency and furnace draft for relation between forced and induced draft. These same factors should be the final guide, whether done automatically or by hand.

Unfortunately, much of the pulverized coal equipment has been rather complicated with a diversity of speeds of both air and fuel, and much tendency for stratification, localized high temperatures and incomplete combustion, while other parts of the furnace are flooded with large excess air. Even with these handicaps such equipment has been very satisfactorily controlled automatically, but with the limitation that the furnaces have had to run with a higher average excess air in order to overcome the faulty stratification of the fuel and air distribution in the furnace.

Another feature, which hampers automatic control, is the limited speed range of motors and other valuable speed drives useable for feeding the fuel and the air to the furnaces. Although few stokers and pulverized coal feeders are properly responsive to the present speed ranges available. When these problems are worked out the application of automatic control will be very simply and effectively done.

The underfeed stoker may be tuned up to deliver the coal and air so as to maintain a uniform fuel bed with certain kinds of coal, but when the quality of the coal changes either as to clinkering property or percentage of ash, it may require readjustment of the relationship or distribution of air in different parts of the stoker. Whether or not these difficulties can finally be overcome rests with the stoker manufacturer, and his success in overcoming them will be the deciding factor in the rivalry now existing between the stoker and pulverized fuel-burning equipment.

A similar situation exists in connection with the chain-grate stoker, which today is usually applied to the free-burning fuel, and is particularly adapted to base load conditions. However, when it comes to responding to variations in load there are certain fundamental difficulties that again may weigh heavily against its continued competition with burning coal in other forms which are more flexible and capable of ease of adjustment without stratification and sluggishness when changing rating.

The coal-burning equipment that is most responsive to complete automatic control will prevail over other methods of burning fuel.

---

*Combustion Control**

By G. S. CARRICK†

AUTOMATIC control methods and machines have been applied to gas-burning, oil-burning, metallurgical furnaces, gas producers, blast furnace gas and by-product coke oven gas. Many control methods were designed years ago. The reason they have not been in use generally is because the control machines used to carry out these methods were faulty—would not stand up under actual operation. Back in the years 1890 to 1895, men like House, Thiell, Beckman and others invented regulators to operate from furnace pressure. These regulators, however, have long since been forgotten and evidently did not work out in practice.

Sixteen years ago Billings invented the method of controlling fuel feed by measuring the flow of gases in the furnace outlet or breeching, and also by measuring the differential pressure taken at two points in the furnace setting.

Twelve or fourteen years ago a Russian invented the method of controlling air to be mixed with blast furnace gas for burning in accordance with changes in pressure of the blast furnace gas.

These inventors were evidently so taken up with the method or scheme that they overlooked the important point—the regulating machine and the actuating medium and power of the regulators.

Today the proper control machines are being built to carry out in a practical way these ideas which were given to us years ago.

There are, therefore, two important factors to consider in connection with the automatic control of combustion. First, the machine or automatic regulators that go to make up any system of control. Second, the system or arrangement or combination of these regulating machines.

---

†President and General Manager, Carrick Engineering Co., Chicago.

*Presented at Fuel Savings Conference, May 13-14, 1925.

The regulators or machines that go to make up any control system are just as important as the systems. The general trend in recent years in all lines of combustion control has been to overlook the machine and to give thought only to the system or arrangement.

I use the term Machine because regulators used in the average plant should be rugged, reliable positive, dependable and capable of doing work and should not be confused with instruments.

Sometimes control instruments can be used advantageously for making minor adjustments in main control units, but control instruments should never be used unless the plant justified an expert instrument man in constant attendance.

The successful operation of any control machine is first dependent on the medium of operation or the substance or device which transmits the changes in gas pressure, air pressure, gas flow or air flow to some power means such as a motor, a cylinder, a diaphragm, or something capable of doing work such as moving dampers, etc. Let us call this device the actuating medium.

There are three actuating mediums commonly used in controls for measuring gas or air pressures or flow. They are, first, a swinging plate in the furnace wall; second, a diaphragh; third, a gasometer or inverted bell, in a water or oil seal. The power of the actuating medium is proportional to its area. There are, however, other things to consider in connection with regulators of this type, namely, the number of working parts, friction and stability. A regulator of this type must be sensitive to a change to one hundredth of an inch and still must not hunt. It must be positive in its action.

There are a number of ways of transmitting the changes in furnace pressure to the power member, some of which include a hydraulic or pneumatic valve, electric contacts, water or air leak ports. The Power member is usually a hydraulic or air cylinder, a diaphragm, or a motor.

Another type of control which is not generally known, but one we have been operating in a plant in Chicago in connection with pulverized coal in an experimental way for more than a year, and which is a success, is a control actuated by a CO_2 machine. This type of control is, of course, actuated by an instrument and must be put in the instrument class and used only to make the finer adjustment in the more rugged control apparatus. It is suitable only for plants where instrument men are in constant attendance to look after the CO_2, indicating and recording machines. This type of control has a future in connection with all types of furnaces.

In steel mill plants I should say that it would be well to use only the rugged machines with few moving parts and all delicate mechanisms eliminated rather than introducing the more complicated apparatus. Machines for measuring gas or air pressures or for measuring and controlling from gas flow and air flow can be built in the rugged types. Electrically-operated machines lend themselves readily to the control of steel mill furnaces. This type of control can always be arranged for manual adjustment or operation by push button.

One of the newer methods introduced in connection with controlling metallurgical furnaces is the method of controlling the gas and air to open hearth furnaces by automatically measuring the flow of gas and the flow of air and simultaneously changing the rate of flow of each in the proper proportions.

This method as well as a method of controlling stoves and gas producers was invented by an engineer in the steel mill business, whom most of you know.

For regulating open hearth furnaces by this method we use a double gasometer or so-called differential gasometer to measure the flow of gas—the same type of machine to measure the flow of air an electric device for adjusting these two machines simultaneously, so that when the operator desires to increase the rate of combustion he makes all adjustments by push button. The standard furnace regulator operating from furnace pressure controls the furnace draft by operating the stock damper or speed of the fans connected with waste heat boilers.

With this method, as in all other control methods the control machines are equal in importance to the method.

CONCLUSION

In conclusion I would like to impress upon you these facts:

First—Giving the same plant personnel proper automatic control equipment will invariably increase the efficiency.

Second—Avoid complicated mechanisms.

Third—Regulators or machines that go to make up any system of automatic control are more important than the system, and no system is better than its weakest component part.

DISCUSSION

H. R. Maxon* You may be interested in the results of applications of fuels to open hearth furnaces, obtained in some experiments, about two years ago.

The furnaces had been oil fired, as regenerative furnaces were impractical on account of the character of the metal.

Believing the temperature could not be obtained with gas, we contemplated using a mixture of gas and oil. The gas furnishing the major portion of the heat and the oil to obtain the temperatures required. These open hearth furnaces we fired first with gas and oil, and then, please note, with gas only. The melting temperature obtained either with gas and oil or with gas alone was 2950 degrees F. and a peak of 3100 degrees F. These particular non-regenerative furnaces, but with waste heat boiler attached, showed over a year's period an over all efficiency of furnace and boiler, of over fifty per cent.

I do not know the amount of fuel used. The amount is not important inasmuch as the efficiency of the unit was better than fifty per cent.

I do not believe a regenerative furnace can show as high an efficiency.

The installation can be repeated in any direct fired furnace. With non-automatic control the flue gas analyses do not vary one-half of one per cent.

Thomas Peebles: I wonder what is the attitude of furnace men as to the desirability of attempting to do on those furnaces what is being done in their boiler plants every day.

*The Maxon Premix Burner Co., Muncie, Ind.

F. G. Cutler†: We have been very much interested in the application of automatic control on metallurgical furnaces. We have realized the benefits that have been obtained by automatic control of boilers, and we have made installations which have given us very materjal benefit. The sticking point for metallurgical furnaces so far as the fuel engineer is concerned is the attitude of the mill operators or heaters with reference to automatic control. We have to have results in order to get the support of the management in getting further installations, and it is a rather hard proposition to educate a heater to benefits of automatic control. We have one or two installations of temperature control on heating furnaces where we maintained practically a balanced pressure in the front part of the heating furnace and think we have obtained very material benefit to the fuel economy, but we all realize fuel economy is not considered when there is a danger of loss in steel. That is the point on which the superintendent of the mill is hard to convince, as to the efficiency of fuel control, if there is any danger of scale or loss in tonnage, and that is the point we are trying to make in bringing out the benefits of automatic control.

G. R. McDermott:*. Some three years ago, Mr. C. L. Kinney and myself presented a paper before the American Iron and Steel Institute in New York City on the "Thermal Efficiency and Heat Balance of an Open Hearth Furnace." That meant, of course, an elaborate test had to be conducted on the furnace and all the necessary observations taken such as coal delivered to the gas producers, temperature readings through-out the furnace system, recording and metering the air flow supplied to the furnace, etc. As a result of our test and observations, we were impressed with the lack of proper combustion regulation. While the test was conducted, the furnace was under the entire supervision of the furnace crew; we made no attempt to adjust air conditions to correct for any combustion irregularities which developed during the test. Through the courtesy of the Bailey Meter Company, we installed a large orifice in a duct before the furnace air valve and by means of a special meter supplied by the Bailey Company we were able to record cubic feet per minute entering the furnace. The coal used by the gas producers was weighed by the hour and as a result, we were able to obtain a log of the fuel flow to the furnace in the form of producer gas and air flow.

We found that with increasing consumption of coal in the producers, which meant increasing producer gas flow to the furnace, there was at the same time actually a marked falling off of air supply to the furnace. The deficiency of air was further indicated by the presence of carbon-monoxide in the waste gases leaving the furnace. No attempt was made to rectify this condition, as we desired to obtain conditions under actual operation with the regular furnace crew. Furthermore, we noted considerable variation in the furnace pressure. In our paper, we called attention to the fact that there was certainly room for improvement in maintaining proper combustion, due to the fact that fuel and air supply were not properly proportioned and we proposed to automatically maintain and control combustion and also furnace pressure.

As the first step along this line, I installed an automatic furnace pressure regulator where an attempt was made to automatically control the furnace pressure by putting in a connection in the roof of the furnace and transferring pressure to the regulating device which controlled the speed of the turbine driving the induced draft fan installed in connection with the waste heat boilers. When first installed, we obtained very good results in maintaining the required furnace pressure and actually the fan gradually slowed down in its speed to meet the furnace requirements from the standpoint of waste gas discharged from the furnace as the heat progressed. However, we were forced to take off the control, due to the unreliability of the particular machine which we were using for maintaining furnace draft. It stands to reason that if there is no change made in the fan speed and consequently draft on the furnace, and with a falling off in the waste gas generated in the furnace, that the fan must be satisfied and it can only be satisfied by air infiltration at the charging doors of the furnace or else in the connecting flues and regenerators.

Recently I was interested in measuring, if possible, the flow of producer gas to an open hearth furnace and to determine to what extent it varied during the period of heat. With this in mind, we installed a plate orifice in the producer gas line and recorded the flow thereby. These records indicated a variation of 10% to 30% in the gas flow due to producer conditions, differences in the friction of gas flow when the furnace was on one side as compared to the other side and during all these variations there was no change made in the air valves. It would be physically impossible to expect the furnace operator to follow such changes. I mention this condition to illustrate the necessity of automatic regulation of air and fuel supply to obtain efficient combustion. Considering what is now being done in the large central station boiler houses on automatic regulation and although the open hearth process is more complex, I consider that there is room for improvements, as I do not believe the operators of open hearth furnaces controlled the combustion with anything like the degree of efficiency that we are now getting on boilers.

J. W. Kagarise*: I think there is a future for controlled air in the operation of the open hearth furnace, and we should work along that line. One of our main troubles is infiltration of cold air through the uptakes, ports and body of the furnace. We are using far more air than we take in at the air inlet, and if we can prevent the infiltration of cold air, I believe we can accomplish much in the conservation of fuel. There is not much use in having the furnace tight below the floor and wide open above. Our furnaces should be tightened up all over to control the air.

E. W. Trexler†: At our plant we have a number of heating furnaces using gas from coke plant that has no gas holder. Nothing to keep the gas pressure constant, about six months ago we equipped

†Chief Bureau of Steam Engineering, T. C. & I. R. R. Co., Ensley, Ala.

*Assistant Chief Engineer, Illinois Steel Comapny, South Chicago, Ill:

*Supt., Open Hearth Dept., Carnegie Steel Co., Braddock, Pa.

†Comb. Engr., Bethlehem Steel Corp., Johnstown, Pa.

several furnaces with gasometer pressure regulators. The results have been surprising. We cut fuel rates; and while it has been a rough regulation, it has shown that regulation is the correct thing to do. We found furnaces with varying gas pressure could not operate on 17 inches of pressure before regulators were installed, and have found we could operate the furnace without any trouble as low as 8 inches of pressure with regulator, and we have also equipped our open hearth the same way. We now have practically no operations using a considerable amount of gas without regulation to hold gas at constant pressure. So far as air for combustion is concerned, haven't done anything to regulate that.

R. W. Simpson*: As to the question of practicability of apparatus now before us. I think the run of six months on Trumbull Steel Company's No. 7 furnace with practically no change in apparatus and no difficulty demonstrates that there is certainly a practicability in the apparatus now available. We are using a Hagan type regulator, especially developed for the job and very little attention has been paid to it. We had to sell it to the men in the open hearth and our first difficulty was in selling it to them so they would leave it alone. About two weeks ago we had some difficulty and had to operate No. 7 furnace without any regulation for about a week. The gas consumption went up to 12,500 cubic feet per ton and they only made 14 heats on that furnace that week. Immediately, we put it back they made 16 and had made 18 the week before it went off. All that week the men were asking how soon we were going to get it back, and from the point of formerly being against regulation they were in favor of it, because it meant something in their pocket, as well as saving to the company in gas.

G. R. McDermott: No doubt it would be difficult to keep the static connections clean over a period of time. I was interested in determining what variation in producer gas flow there was to the open hearth furnace. When the static connections were blown out once a day, we were able to obtain a twenty-four hour record, using a Bacharach hydrometer. The records as obtained indicated variation in gas flow to the extent of 10 per cent to 30 per cent, regardless of the producer or furnace operators.

Walter de Fries†: What kept the orifice in the line?

G. R. McDermott: An 80% orifice made of 3/16" plate was introduced in the frame of the sand damper of the producer gas main.

G. R. McDermott: I would like to inquire how they are controlling gas pressure at Trumbull furnace?

R. W. Simpson: We installed the pipe about 3' above the tap hole for the purpose of maintaining a balanced pressure. The difficulty we ran into at Warren was that the draft capacity of the exhaust fans allowed very little play, as most of the time they are operating at their maximum number of revolutions. For some reason or other we have not been able to enthuse the Trumbull Steel Co.'s man with the problem of draft regulation, although it was in operation for some time, but was subsequently taken off and we have since relied on hand regulation. In the new installations which we are making, we are providing draft regulation and expect further improved results."

G. S. Carrick: It is not a difficult matter to make a machine to function to properly control either flow or pressure of air or gas. It is simply a matter of taking machines already in use in connection with automatic control of combustion in power plants and adopting them for use in steel mills. These machines have proven successful over a number of years of continuous operation. It is important to select the machine having the proper actuating medium. It should be of sufficient size to give proper sensitiveness and should also be positive. There is no difficulty in manufacturing equipment. It is a question of getting the size to meet the conditions, something that is practical and something that will fit the rugged requirements of the steel mill.

C. H. Smoot: As to the practicability of regulating apparatus, it may be stated that their use is well established in boiler rooms where conditions are, if anything, worse than in steel plants. In a number of large public utility steam plants, machine control and regulation are giving very serviceable performance with low maintenance and upkeep charges.

As to Mr. Carrick's statement that by making a regulator big enough sensitiveness can be obtained, I want to point out that there is a limit as to the size; because too large regulating apparatus is likely to be too slow and too sluggish for accurate regulation. In other words, the desired results are delayed. Some precaution is necessary and considerable engineering judgment.

As to the proper power required for regulating purposes, it is essential to provide for an ample safety factor. If five pounds are needed, 40-50 pounds are supplied. This is done for psychological reasons, to create confidence of the operating men. It has happened that one failure due to lack of power has caused many regulators to be condemned in conjunction with all their accessory equipment.

As to the attitude toward the combustion control problem, it may be helpful to look at it in the following way: On the one hand, engineering specialists, having made a study of regulating apparatus, are offering their machines to the steel industry. On the other hand, practical operators have certain regulating problems they want solved. These two kinds of engineers have to come together, they have to co-operate in a friendly spirit. The one stating what he wants done, deciding the importance and value of the factors to be regulated in a certain way, and the other adapting his machines and devices to satisfy those requirements. It is imposible for the one to dictate to the other; it is a matter of mutually satisfactory help, where both parties have to meet each other half way. Adapting machines means installation with engineering service for the one party, and complete confidence in the advantages of machine control over manual regulation for the other party.

---

*Open Hearth Manager, American Heat Economy Bureau, Inc., 926 Wabash Bldg., Pittsburgh, Pa.

†Fuel Engineer, Pittsburgh Steel Co., Monessen, Pa.

Most of the regulating problems exist, but are not recognized as such, because they are intricate and interlinked with matters of judgment and opinion. In other words, they are hooked up with the human element. A number of industrial applications which required remarkable skill on the part of the operator to get results, were reduced to simple labor operations by proper regulation. The rarely developed skill was unfailingly reproduced by simple machines, regulating so as to duplicate conditions with a precision and accuracy superior to any human machine.

It is up to you, steel and blast furnace engineers, to state your problems correctly and to formulate the demands of your processes, and it is up to us regulating men to make our machines satisfy these needs and requirements.

E. G. Bailey: I would like to make some remarks in regard to selling automatic control or anything else to the operating men. I have a great deal of respect for the operating man. I find those fellows know their work and use more intelligence than we sometimes give them credit for. I also find you can't put anything over on them. Your control of equipment has got to be pretty nearly right before they will take it. As a rule, when you find operators are not enthusiastic about anything new, then you had better develop the equipment to a little better state of perfection.

Going back to the question of CO_2 recorder, the fireman would open the fire door and expect the recorder to drop immediately, and when it did not, he would say it was no good. The average operator will put every piece of equipment you install on his furnace through some such test as that. Perhaps he forms conclusions prematurely, but it is your business to see that he has the proper undertanding of the matter. Don't put equipment onto a furnace and tell a man it is going to show him up. Always put it on with the idea of co-operation. Understand the ability of that man and help him make a better man of himself, more of an engineer to get better results and not as a tell-tale. You fellows in charge of furnaces know the situation as well as the engineering problem which Mr. Smoot brought out.

As manufacturers, we cannot go into a plant and carry out that scheme. The psychology and study of human conditions in your organization; the attitude of the boss has a great deal to do with the attitude of his assistants. It may be somebody higher up than you or your assistants, but the furnace man will reflect what he think his boss or somebody higher up wants him to reflect. So there is quite a study of human nature in applying engineering to practical operation of plants.

Usually, the manufacturer is not 100 per cent, but he wants co-operation from you engineers. So let us study the human side, as well as the engineering and mechanical.

F. W. Manker*: I wonder if I could suggest one or two considerations which might be of interest. The regulators that we have been discussing, as I take it, have for consideration the desirability of measuring relative volumes of waste and fuel, either solid fuel, weight or volume of gas. What we are trying to do in a furnace is to get combustion, and wouldn't it be the proper thing to attack the problem from the analysis of your combustion, and regulate the means of getting the effect in your furnace through the combustion itself? For a good many years, there have been equipments on the market which measure gas, and this equipment over a range of operations sufficient to give flexibility will determine how to analyze them in conditions you want in your furnace. With such equipment as this, you eliminate the necessity of mechanical means of proportioning your fuel to your air. When it comes to open hearth operations, might that be one of the factors that should be considered so as to have a means of controlling the ratio of gas to air by the products of combustion at combustion points, regardless of excess air or infiltration in furnace, and if you can, then you can compensate for different B.t.u.'s of gas content you are feeding into the furnace. If you are depending on mechanical means; if you are feeding 500 B.t.u. now and 525 B.t.u. 15 or 20 minutes later, you are not going to get accurate mixture.

G. R. McDermott: I am under the impression one of the speakers this morning claimed he was operating a furnace under those conditions.

W. Dyrssen*: I would like to know if the trouble with automatic regulators due to "hunting" has been overcome. In many cases, it is undesirable to make it too sensitive. For instance, if we put a regulator for the steam pressure on a boiler for regulating the speed of the stoker and the fan, it will take some time before the steam pressure is influenced.

I have personally seen a boiler installation where the "hunting" of the regulators was so bad that it was sufficient reason in my mind to condemn the whole automatic regulating installation.

I would also like to know if there is any installation in this country where automatic regulation has been employed by using a CO_2 recorder in the waste gases.

C. H. Smoot: With reference to the general remarks on hunting regulators, at this stage of the regulator development I can only state that a regulator which hunts or races is badly designed, and the fault for the hunting lies with the engineer who designed the regulator and its installation.

There are in existence today many regulators which are rapid, sensitive and stable. The engineering development necessary to accomplish this result is fully completed and well known, if sufficient study and ability is brought to their application. A complete regulator will not hunt, nor is there any necessity to sacrifice accuracy of regulation in any marked degree to obtain stability.

We all carry in our pockets a marvelously accurate mechanical speed governor—our watches. We have no apparatus of measurement whose percentage of accuracy is greater than that of a good time piece, and this is nothing more nor less than an accurate and stable constant speed governor. A watch may have an error of a few seconds a month, which corresponds to a percentage error almost too small to represent as a percentage.

---

*Vice President, Surface Combustion Co., New York City.

Chief Engineer, Blaw-Knox Company, Pittsburgh, Pa.

There are two well known types of regulator, which are both stable and sensitive. I refer to the Tyrell regulator, used on electrical machines and the inertia type Rites governor, used extensively on steam engines. Both instruments are dependable, accurate, stable and sensitive. It is interesting to note that both instruments contain the same identical characteristics. They both respond to rate of change of the property being regulated, as well as to changes in value, independent of the rate of change. The inertia governor, for example, opposes any change of speed by the inertia element, which acts rapidly and serves the purpose of maintaining the status quo without loss of time. In addition the fly ball counterpoise by the regulating spring regulates for a constant speed. Either element alone will not produce a satisfactory governor, but both elements together produce a governor whose charactertistics and action are as near perfect as our engineering conception allows us to produce.

In the Tyrell electric governor the vibrating element responds to changes of condition, but with a strongly marked characteristic giving stability. This is a rapid acting element in the governor, with a characteristic and a strong degree of stabilization. It opposes a change of condition and responds immediately to all changes of the voltage being regulated. The slow acting element is devoid of characteristic and acts to continually readjust the stabilized quick acting element. Any effort readjusts the setting of the quick acting element, and with time delay, eliminates the load characteristic of the quick acting element, returning it always to a constant potential setting, thus the quick acting element responds in a rapid manner to changes, while the unstable constant potential element responds slowly to changes and readjusts continually the setting of the stabilized parts of the regulator.

All regulators worthy of the name have two distinct systems of forces and elements, illustrated by the two governors above, and no governor is a real governor if it be not rapid in response to changes of condition with stability and at the same time be capable of resetting to a constant value with a more retarded action the governor balance.

Unfortunately, many so-called governors or regulating apparatus are constructed with the unstable constant value regulating element only and are not provided with a stabilizing quick acting element, corresponding to the inertia weight on the speed and the rapid acting solenoid of the Tyrrell regulator.

In a steam boiler plant the steam pressure regulator must respond to changes of pressure without loss of time and at the same time be adjusted with loss of time to return any error in pressure to the inertia value which is desired.

The characteristics of an adequately designed pressure regulator in a boiler plant are stability and uniformity of pressure, but this is always associated with a momentary rise and fall of pressure corresponding to a momentary change in load, an increase in load causing a momentary reduction in pressure which the slow acting unstable portion of the regulator progressively compensates for. The quick acting stable element of the governor increases the boiler heat input with drop in steam pressure and decreases the steam input with a rise in pressure.

Here, again, you have the two elements acting in conjunction to produce a sensitive and stable regulation. Similarly throughout the plant each element regulated requires for satisfactory operation a similar piece of apparatus.

If a regulator hunts, it has been badly designed, and only a part of the engineering work necessary to produce a regulator has been incorporated. It is a comparatively easy matter to analyze any governor design and determine whether or not it is a complete piece of apparatus.

The question to ask is, "Does this apparatus respond to the value of the quantity being regulated and at the same time does it respond to the rate of change, or has it two force elements, one of which responds rapidly to a change of condition with a stabilizing characteristic, and the other a force balance which responds slowly to the element being governed without a stabilizing characteristic." The omission of either characteristic invariably produces an unsatisfactory regulator, which is inaccurate in result produced or in continued oscillation, either rapidly or slowly giving a produced result alternately above and below the value desired.

K. Huessener*: Owing to the pressure of time, I wish to confine myself to just a few words about a new development in the Open Hearth field, which I am sure will interest you.

As at last some of you know I always have been very strong in my ideas as to how the Heat Transfer in an Open Hearth Furnace really takes place, and have arrived at the conclusion that it is to the extent of about 90 per cent by radiation and only 10 per cent by convection. Until quite recently the general belief prevailed that radiation was always combined with luminosity, it was very hard to explain how, for instance, the heat transfer of a coke Oven Gas Flame which is entirely non-luminous, could be accounted for. Since then the radiation properties of non-luminous gases, as far as they are constituted of two moleculars have been discovered, and fully explain why heat transfer by radiation in the absence of luminosity is possible. Starting from the fact that nearly the total work in the Open Hearth furnace is done by CO_2 and H_2, it became evident how essential it must be to keep the percentage of these two constituents of the products of combustion as high as possible, which in turn called for automatic regulation.

Our first experiments in automatic regulation on Open Hearth Furnaces were conducted at the Trumbull Steel Company, in Warren, O. To obtain this regulation, we had to put the combustion air under pressure and then automatically regulate the quantity of air entering the regenerators from the quantity of gas entering the furnace. The principle employed on the first furnace equipped is the same as that used in the well known Steinbart combustion system. In this case the static pressures set up in special stabilizing boxes by gas and air were used. Subsequently it was found that, owing to the restriction in areas of the regenerators, as the furnace got older, the regulation required frequent changes in the gas and air pressure

*President American Heat Economy Bureau, Inc., Pittsburgh, Pa.

relation, and therefore on the second furnace to be equipped we utilized the differential pressure set up by orifice plates installed in both gas and air mains for the purpose of automatic regulation. The superiority of the second system over the first was at once evident, and it is the second system which we are now using on all our later installations.

The results obtained in both cases were extremely gratifying. The gas consumption in the first furnace equipped was reduced from 12,500 to 13,000 cubic feet per ton of steel to in the neighborhood of 9,000 cubic feet, and in the case of the second furnace, to about 8,100 cubic feet. These figures are monthly figures, and include losses for all delays including repairs. The number of heats which rarely exceeded 14 per week prior to our installation increased to an average of 16 and a peak of 18 heats. The product manufactured at Warren, O., is low carbon steel .09 to .12 Carbon, and is rolled into cold rolled strips, much of it for nickel plating. The high quality of the product was in no way influenced by the speed of the heats.

In watching combustion in the Open Hearth Furnace it is interesting to note how very definitely the results obtained are dependent on the composition of the products of combustion. We have run an Open Hearth Furnace at temperatures which were always perilously near the melting point of the brick with an excess of air of 100 per cent, a second heat with an excess of air of 10 per cent and a third time with a deficiency of air of 50 per cent. The heat with an excess of air of 10 per cent gave by far the best results, not only as far as fuel consumption per ton of steel, but also as far as the time of the heat was concerned. This is particularly interesting as, so far as we were able to govern it, we run all three heats with approximately the same flame temperature.

From this point of view it will be interesting to find out how the operation of an open hearth furnace could be helped by artificially changing the composition of the products of combustion by the addition of CO_2 from outside sources, or better still by adding to the gas certain Hydrocarbons, which are high in carbon, and therefore will decompose before combustion. Experiments in this direction are under consideration now, and we hope to be able to report about them at one of your future meetings.

After our conspicuous success with coke oven gas regulation we turned our attention to producer gas fired furnaces. The regulation here is not so simple, as it is extremely difficult to measure hot producer gas, which carries large quantities of impurities which make it difficult, if not impossible, to install orifice plates and maintain them operative. After attempts in various directions we have found a system which we think offers a rather strikingly simple way out of the difficulty. Provided half way normal operation of producers, which particularly with mechanically poked producers is rather easy to obtain, a pound of coal requires a given quantity of air to be gassified, it yields a given quantity of gas of pretty uniform composition, and this gas again requires a stated quantity of air to be completely burnt. It will, therefore, be seen that there is a fixed relation between the quantity of air required to make the gas and the quantity necessary to burn the gas. We, therefore, decided to regulate the combustion air from the air required to run the producer. For this purpose, of course, it is necessary that each furnace has its separate producers. In the case of No. 5 Furnace at Trumbull Steel, we supplied a turbine driven fan to supply the air to the producers. The turbine was chosen of such water rate that the exhaust steam of the turbine supplied sufficient steam to the producer. Orifice plates were put in both air lines to the producers and to the regenerators and the differential pressures set up in both lines used as regulating factors.

Although at present the furnace has not been run long enough to allow of any definite conclusions the results so far obtained are surely extremely encouraging. The furnace has not only been speeded up very considerably, but the fuel consumption has already been reduced by more than 20 per cent. At the present moment the roof is still being seasoned, so that the furnace has not yet been forced. As soon as normal operation has been reached we expect considerably better results.

G. S. Carrick: I have been operating for the past year and a half an automatic control on a pulverized fire plant, using a CO_2 analyzing machine to adjust or make corrections in rugged control machines. The CO_2 control simply actuates or adjusts another control. As far as controlling direct from flue gas analyzing instruments is concerned, I believe it is better not to place too much dependence on instruments but to use the CO_2 instrument to make the finer adjustments in the more rugged and practical control machines. We are using our standard furnace control equipment with CO_2 control as an adjusting or correcting factor. An adjusting motor on the standard furnace regulator is operated from the CO_2 analyzing machine by electrical contacts. We have used several different types of CO_2 recorders. On one type of machine that we are using a galvanometer measures the CO_2 content in the furnace gases. A timing motor operates a depressing bar on the CO_2 machine every thirty seconds. If, when the depressing bar descends the CO_2 content has varied from the predetermined amount, a high or low contact is made. This contact operates a motor to adjust the standard furnace regulator, which changes the secondary air. At the same time a second motor operates to change the ratio of primary air to coal feed. The amount of the adjustment is timed by a cam. If this adjustment has resulted in restoring the CO_2 to the predetermined amount, then at the next depression of the depressing bar no further adjustment is made. But if the CO_2 content has not been restored, the CO_2 control continues to make corrections at intervals of every 30 seconds until the CO_2 is corrected.

In controlling any kind of a furnace, it is essential to put on rugged machines that are sure to operate. For example, in controlling open hearth furnaces, the control machines should be rugged regulators that measure the flow of gas and the flow of air. For still better regulation and in plants where instrument men are in constant attendance, the CO_2 control can be added to make minor adjustments in the more rugged machines. I think that will be the final answer to the control of powdered coal and the control of steel mill furnaces.

*Insulation of Hot Surfaces and Furnace Walls**

By L. B. McMILLAN†

A MEASURE of the importance of heat insulation in an industry is the extent to which processes employing heat are used, and in no line of manufacturing endeavor is there a wider variety of heat-using processes than in the Iron and Steel Industry. Here will be found all of the insulation problems encountered in connection with steam generation and power plants, and a host of others in addition. Among the latter are a great many furnaces and ovens using large quantities of heat and offering attractive opportunities for economies through the use of insulation. On many of these, insulation has already been used and has proved its merit, but there are still a great many places where large savings may profitably be effected by the use of suitable insulation.

Losses from Bare Heated Surfaces

Consideration of the extent of losses from highly heated surfaces without insulation is of primary importance because the magnitude of these losses is such that, once this is realized, it is immediately apparent that a substantial reduction would be highly desirable. Engineers recognize the fact that operation with bare steam pipes would be poor economy, yet the same attention has not been given to other heated surfaces. Figure 1 shows how the heat losses increase as the temperature difference between hot surface and surrounding air increases. This curve is based on still air conditions, air temperature 80° F., and shows the heat losses from dull surfaces, such as oxidized metal, brick, etc. It may be added that these losses vary somewhat with different sizes and shapes of surfaces, and that they increase slightly as the absolute temperature of the air is increased. However, these variations are small compared with those which, as will be shown later, might be caused by slight air currents, therefore the curve may be said to represent conservative values of bare surface losses.

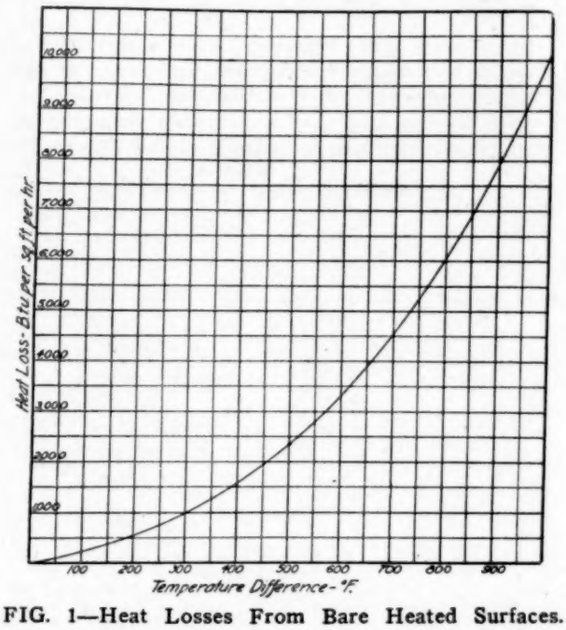


FIG. 1—Heat Losses From Bare Heated Surfaces.

Heat losses expressed in B.t.u. are not usually as significant as when expressed in the equivalent actual cost in dollars. In Figure 2 the equivalent losses in dollars per sq. ft. per year, 8,760 hours, have been shown for various values of heat per 1,000,000 B.t.u. This is considered preferable to expressing the losses in equivalent pounds of coal or other unit of fuel, because in the Iron and Steel Industry there are so many different kinds of fuel and sources of heat that a chart based on one fuel and one efficiency of utilization would mean very little for any other condition. On the other hand, in any given case the value of heat per 1,000,000 B.t.u. is either known or may readily be computed for a given fuel of known cost and a given efficiency; thus this procedure renders Fig. 2 applicable to a wide range of fuels and conditions. Taking as a specific example, a boiler drum operating 7,200 hours per year at a temperature 300° F. above that of the surrounding air, the loss per sq. ft. per year at a value of heat of 30 cents per 1,000,000 B.t.u. is $\$2.60 \times \frac{7200}{8760} = \$2.14$. Suitable insulation saving about 90% of this heat loss may be applied at a cost considerably less than one year's saving. This illustrates the desirability of insulating such surfaces as boiler heads, flanges and fittings, which are frequently left uninsulated even though adjacent piping is provided with effective insulation. The effect of in-

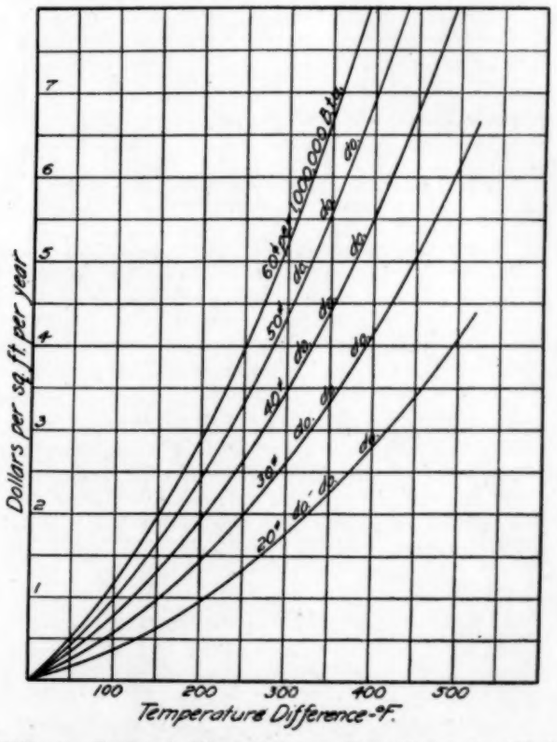


FIG. 2—Cost of Heat Losses Per Year At Various Values of Heat Per 1,000,000 B.T.U.

*Presented at Fuel Savings Conference, May 13-14, 1925.

†Consulting Engineer, Johns-Manville, Inc., New York City.

sulation on losses from furnace walls will be discussed in a subsequent part of this paper.

Effect of Air Velocity on Surface Losses

The rate of heat loss from a surface maintained at a given temperature is greatly increased by air circulation over the surface. This is illustrated in Fig. 3, which shows the factors by which losses under still air conditions must be multiplied to find the loss at a given velocity. These curves are based on Langmuir's equations for convection and increase in convection losses due to air velocity.[1] Many other investigators have shown increases in rates of heat loss of much greater magnitude. In fact some[2] show increases approximately double those illustrated in Fig. 3, and T. S. Taylor[3] has shown that still further increases may occur if air currents strike the surface obliquely instead of flowing parallel to it or impigning directly upon it. Therefore, the values represented by the curves in Fig. 3 may be regarded as showing conservatively the minimum effects of air velocity, and in a given case the effect will probably be much greater rather than any less than these values.

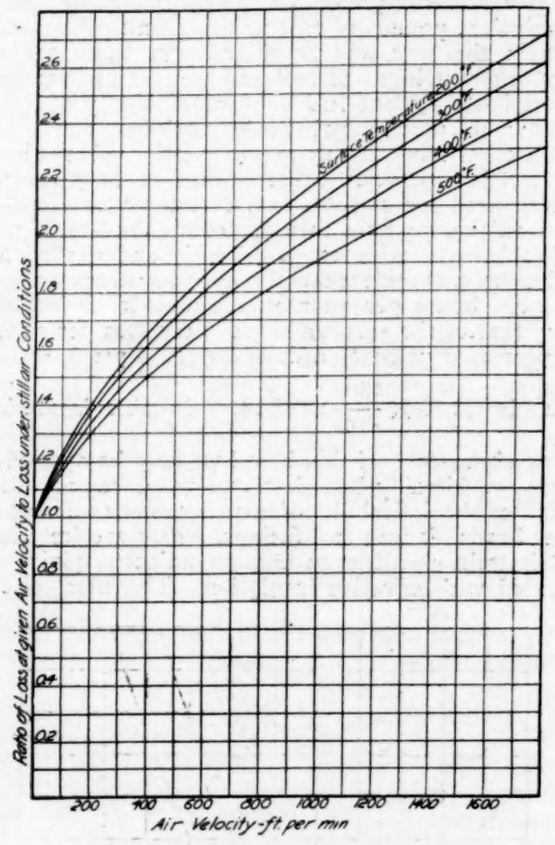

Ratio of Loss at given Air Velocity to Loss under still air Conditions
Surface Temperature 200°F.
300°F.
400°F.
500°F.
Air Velocity - ft. per min

FIG. 3—Factors Showing Relative Losses At Various Air Velocities As Compared With Still Air Losses As Unity.

The reason for the different rates of increase for surfaces at different temperatures is that heat transmission from surfaces takes place partially by convection and partially by radiation. Air circulation affects only the convection. At a temperature of 400° F., the radiation component which is unaffected by air velocity is a larger proportion of the total transmission than it is at 200° F., consequently a given increase in convection affects the total less at 400° F. than at 200° F. For temperatures less than 200° F. the convection component tends to decrease more rapidly than the radiation component, so that the curve for 100° F. would lie near that for 300° F.

In spite of these variations in increase factors, however, the losses are materially increased by air velocity at all temperatures. This point is brought out more clearly in Fig. 4, in which total losses are shown for various temperature differences for each of the following velocities: 0, 200, 400, 800 and 1,600 feet per minute. It is apparent from these curves that air velocity is almost as important a factor in determining heat loss from a surface as the temperature difference between the surface and surrounding air.

Effect of Air Velocity on Losses from Insulated Surfaces

In the case of well insulated surfaces the increases in heat losses due to air velocity are very small as compared to the increases just shown for bare surfaces. This is due to the fact that air flowing over the surface of the insulation can increase only the rate of heat transfer from surface to air and cannot change the internal resistance to heat flow inherent in the insulation itself.

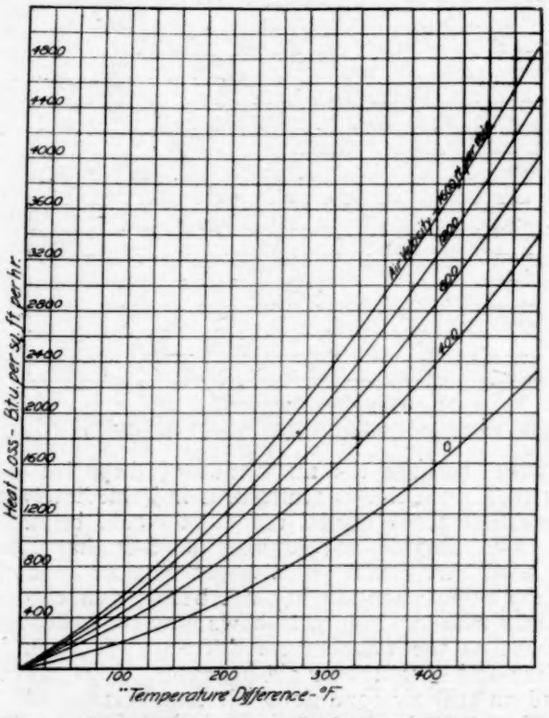


FIG. 4—Heat Losses From Surfaces At Various Temperatures and Exposed to Different Air Velocities.

The effect of the air circulation, therefore, is to cool the surface of the insulation to a temperature lower than it would have under still air conditions,

[1] Transactions American Electrochemical Society, Vol. 23.

[2] A. C. Willard and L. C. Lichty, Bulletin No. 102, Engineering Experiment Station, University of Illinois.
T. S. Taylor, Transactions, A.S.M.E., Vol. 42.
J. A. Moyer, Journal A.S.R.E., November, 1915.

[3] Transactions A.S.M.E., Vol. 42.

thereby increasing the temperature drop through the insulation. This is illustrated in Fig. 5 by the decrease in temperature from t_2 to t'_2. Since the heat transfer in a given case is proportional to the temperature gradient, it is obvious that the heat flow

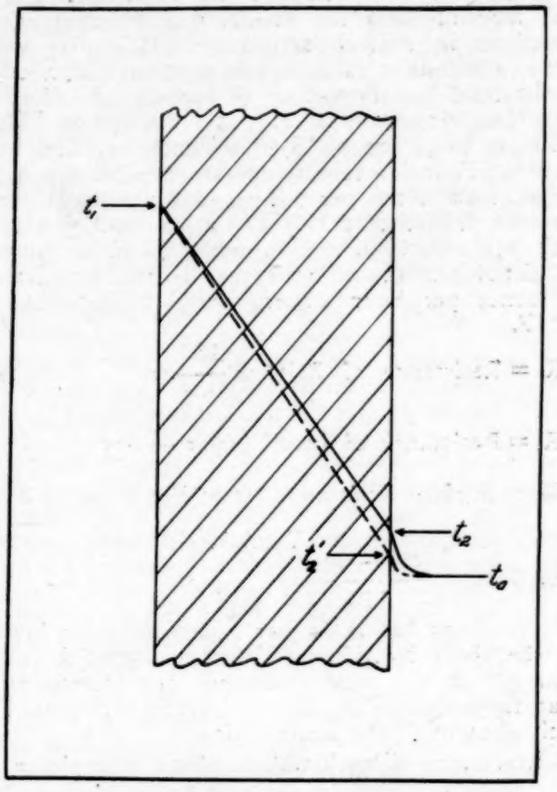


FIG. 5—Temperature Gradients Through Insulation (the Dotted Curve Represents Temperature Gradient When Surface of Insulation is Subjected to Air Circulation.)

will be greater when the temperature difference is t_1—t'_2 than when it is t_1—t_2 and that the increase in heat transfer is proportional to

$$\frac{t_2 - t'_2}{t_1 - t_2}$$

In the case of outdoor surfaces the combined effect of wind and rain may bring the surface temperature of the insulation practically down to the air temperature, yet even in this extreme case the increase in heat loss through the insulation is not as great as might be expected. This is illustrated by the following example: Suppose that a flat surface is insulated with 2" thick insulation, having a conductivity of 0.5 B.t.u. per square foot per degree temperature difference per 1" thick per hour, and that the rate of heat transfer from its surface to air under still air conditions is 1.8 B.t.u. per square foot per hour.

$$\text{Internal resistance of insulation} = \frac{2}{0.5} = 4.0$$

$$\text{Surface resistance} = \frac{1}{1.8} = \frac{.556}{}$$

$$\text{Total resistance} = 4.556$$

$$\text{Rate of heat transfer} = \frac{1}{4.556} = .22 \text{ B.t.u. per sq. ft. per deg. temp. diff. per hr.}$$

If surface resistance were completely eliminated due to the cooling action of wind and rain, the internal resistance of 4 would still remain, and the rate of heat transfer would be $\frac{1}{4} = .25$ B.t.u. per square foot per degree temperature difference per hour. Therefore, the maximum increase in loss due to wind and rain would be $\frac{.25 - .22}{.22} = 13.6\%$.

In like manner, it may be shown that the maximum increase in 1" thickness of the same material under the same conditions is 27.9% and, in the case of 3" thickness, 9.2%. It is therefore apparent that the thicker or the more efficient an insulation is, the less its rate of heat transfer will be affected by air circulation.

Fig. 6 shows graphically the relative increases, due to air circulation in the case of a bare surface

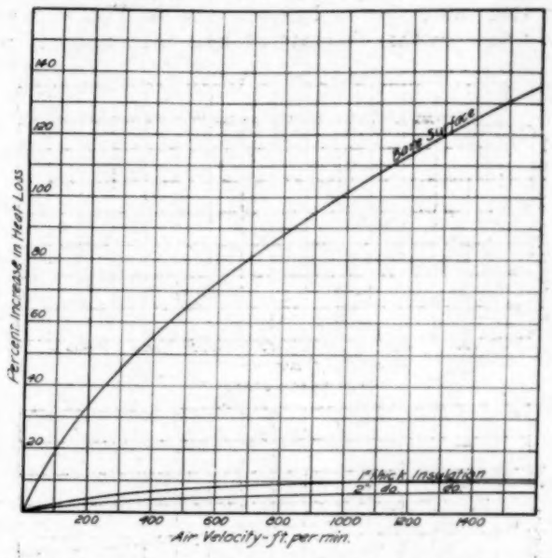


FIG. 6—Increase in Heat Losses Due to Air Circulation.

maintained at 400° F., and the same surface insulated with 1" and 2" thicknesses of an insulation with a conductivity of .48 B.t.u. per square foot per degree temperature difference per 1" thick per hour.

All of the above discussion as to effect of air circulation on losses through insulation is based on flow of air over the surface of the insulation, and applies to cases where the insulation is tightly sealed. If the condition of the insulation is such that the air may

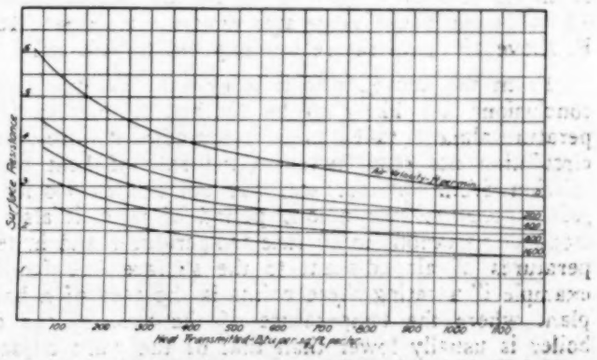


FIG. 7—Surface Resistance As Affected By Air Velocity.

circulate through cracks and crevasses in the insulation, the increases may be far greater than those given above. Therefore, it is essential that all insulation be sealed as tightly as possible, and that, in case of pipe insulation out of doors, a weather-proof jacket amply lapped and thoroughly sealed should be provided. Other outdoor insulation where not applied inside a steel shell should be thoroughly weather-proofed.

Effect of Air Velocity on Losses Through Furnace Walls

Air circulation over the surface of a brick wall increases the rate of heat transmission from the **surface** according to the factors shown in Fig. 3, and as pointed out above this tends to cool the surface and increase the heat loss through the wall. Therefore, while the increase in heat loss is not as great as for surfaces maintained at constant temperature, the outstanding fact is that, with a **lower surface temperature, the wall is transmitting more heat.** This fact may be illustrated more clearly by reference to Fig. 4, where it may be seen that the rate of heat transmission from

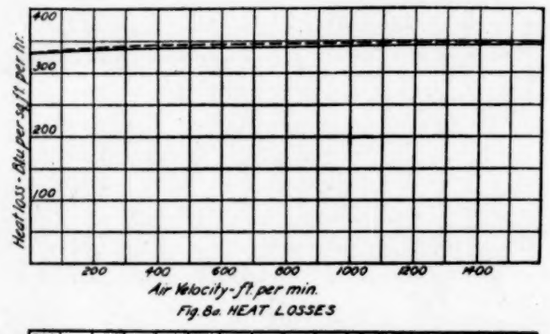


FIG. 8—Effect of Air Velocity on Heat Losses and Surface Temperature of Insulated Wall.

a surface 100° F. above air temperature and exposed to an air velocity of 400 ft. per minute (approximately 4.5 miles per hour) is greater than for a surface 150° F. above air temperature but exposed to still air.

From the above facts it is evident that misleading conclusions are likely to be reached if surface temperature alone is taken as an index of heat losses. Air circulation not only increases the rate of heat transmission from the surface, but since the velocity is rarely constant over a long period of time, it also introduces variations in surface temperatures and in temperatures of air adjacent to the surface. A familiar example illustrating these points is the case of a boiler plant where the temperature of the wall of the end boiler is usually lower than that of the walls adjacent to the alley between batteries yet, other conditions being the same, the loss from the more exposed wall is undoubtedly the greater.

In the case of insulated walls the variation in rates of heat transmission due to air circulation is less than for walls without insulation; because, as pointed out above, the higher the total resistance to heat flow the less the results will be affected by variations in surface resistance. However, while these variations in surface resistance have little effect on the total heat flow, they do have a marked effect on surface temperatures. This is illustrated in Fig. 8, which is based on a 13½" thickness of fire brick at 2000° F. inside face temperature, with a conductivity of 7.5 B.t.u. per square foot per degree temperature difference per 1" thick per hour, insulated with 2½" thick insulation with a conductivity of 0.7 B.t.u. per square foot per degree temperature difference per hour. Surrounding air temperature 80° F.

R_b = Resistance of Brick $= \frac{13.5}{7.5} =$ 1.80

R_i = Resistance of Insulation $= \frac{2.5}{0.7} =$ 3.58

R_s = Surface Resistance (from Fig 7) = 0.42

Total Resistance 5.80

$$\text{Heat loss} = \frac{2000-80}{5.80}$$

= 331 B.t.u. per square foot per hour.

The above individual resistances expressed as percentages of the total resistance are interesting in that they show the relative effects contributed by each element of the construction:

Resistance of brick wall in above example = 1.8

$$\frac{1.8}{5.80} = 31.1\% \text{ of total}$$

$$\text{Resistance of insulation} = \frac{3.58,\ 3.58}{5.80} = 61.7\% \text{ of total}$$

$$\text{Surface resistance} = \frac{.42,\ .42}{5.80} = 7.2\% \text{ of total}$$

It is apparent, therefore, that the insulation offers much the greater part of the total resistance to heat flow, and that the loss from the insulated wall is small as compared with that from uninsulated wall. Computations similar to the above for the wall without insulation, other conditions being the same, show a heat loss of 909 B.t.u. per square foot per hour. Therefore, the saving by insulation is 578 B.t.u. per square foot per hour. At a cost of heat of only 20 cents per 1,000,000 B.t.u., this saving is equivalent to $1.10 per square foot per year. If the walls were exposed to air circulation, the saving would be even greater, because the increase in loss from the uninsulated wall would be much greater than for the insulated wall.

Reference to Fig. 8 illustrates clearly the fact that surface temperatures do not give a reliable measure of conduction losses. In the first place, the effect of air circulation is to increase the heat losses and to decrease the surface temperature. Therefore, under these circumstances, the lower surface temperatures are by no means indications of a lower heat losses. It was pointed out on page 302 that the increases in heat transfer from surfaces due to air

circulation might in some cases be much greater than those shown in Fig. 3. The solid curves in Fig. 8 are based on the factors given in Fig. 3, while the dotted curves represent what would occur if the increases in surface losses were double those given in Fig. 3. It is apparent that the heat losses through the insulated wall would be changed only very slightly, but the surface temperature would be still further decreased. In addition to variations due to air circulation, there are other effects, such as nature of the surface and exposure to other hot or cold surfaces which introduce additional variables affecting the relationship between surface temperatures and heat losses. While these variables have relatively little effect on the total heat transmitted through an insulated wall, they may have entirely disproportionate effects on surface temperatures.

The temperature drop through each element in the construction is given approximately by the multiplying of the percentages in the example on page 304 by the total temperature drop from inside surface to surrounding air, 1920° F. in the above example. However, the temperatures actually obtained at various points in the construction are usually lower than values calculated in this manner because of conduction of heat along the wall itself from the high temperature zone to cooler parts of the wall. Where there is a relatively large amount of air infiltration, the temperatures will be much lower than the calculated values. However, insulation may be applied in a manner to reduce effectively the losses due to this infiltration, as well as the losses due to conduction through the wall. Boiler wall coatings are sometimes used, even on furnaces other than boiler furnaces, to prevent infiltration, but these are not insulations and offer practically no resistance to conducted heat. On the other hand, insulation may be made to serve a double purpose, with the result that the combined savings from reducing conduction losses and infiltration losses greatly exceed the savings due to its insulating value alone.

There are certain cases, such as open hearth furnaces and blast furnaces, where limitations of available refractories are such as to make the reducing of heat flow inadvisable, yet equipment adjacent to these furnaces, such as regenerator chamber walls, hot blast stoves, mains and bustle pipes, may be insulated with excellent results. Among the other places where insulation may profitably be used, are: Heating furnaces, annealing furnaces, heat treating furnaces, and coke ovens.

Within the limitations of refractories as to temperature, the effect of insulation on the furnace walls, suitably proportioned and properly applied, may be regarded as beneficial rather than otherwise; because the use of insulation results in more uniform temperatures in the wall, and it is unequal expansion rather than expansion alone that is most injurious to walls. The maintaining of more uniform temperatures tends to prevent cracking of the wall, and to minimize the inequality of stresses which result in the spawling of the bricks. An example of this is the effect of insulation in decreasing damage to brick due to shock stresses during heating and cooling of walls.

Economical Thickness of Insulation

As the thickness of insulation used in a given case is increased the cost of heat lost is decreased, but the cost of insulation is increased. This is illustrated in Fig. 9, in which curve "m" represents cost of heat lost per year, and curve "n" represents the cost per year of insulation. The yearly cost of insulation is the first cost multiplied by the percentage of annual fixed charges, which include interest, depreciation, etc. In industrial plants these annual fixed charges are usually taken at about 20%.

Curve "y" represents the sum of the costs of heat lost per year and the cost per year of insulation. In other words, it may be said that "y" represents the total cost per year of maintaining a given operating

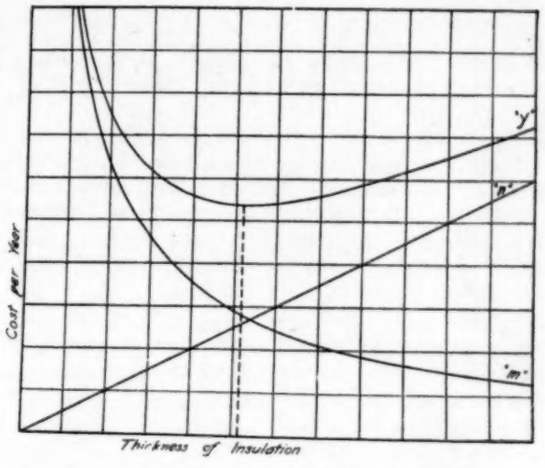


FIG. 9—Economical Thickness of Insulation.

temperature. It is obvious that the economical thickness is the thickness at which this total cost is a minimum. It will be noted that the lower portion of the curve "y" is relatively flat; therefore, hair-splitting refinements in the attempt to determine the exact economical thickness to a small fraction of an inch are uncalled for. On the other hand, when the insulation is much too thin the total cost is too high, because of excessive heat loss. Likewise, when the thickness of insulation is greater than required, the total cost is again too high because of the increased cost of insulation. In the case of furnace walls, it may be said in general that consideration of cost of heat lost and cost of insulation tends to show that even greater thicknesses of insulation than those ordinarily used would be justified. Therefore, it is evident that where insulation is used under these conditions it is paying a high rate of return on the investment represented by its cost.

Hot Blast Stoves, Mains and Bustle Pipes

On account of their location out in the open, exposed to wind and weather conditions, the insulation of hot blast stoves is very important, and considerable attention has been given to providing them with suitable insulation. The loss from these stoves without insulation is from 10% to 20% of the amount of heat supplied. The magnitude of these losses is illustrated in the typical heat balance of a hot blast stove of highly efficient design, but without insulation, given in Table 1.

Table I—Heat Balance of Hot Blast Stove

	B.t.u. per hour	Per cent
Total heat delivered	13,650,000	100.00
Absorbed by dry blast	9,590,000	70.25
Absorbed by moisture in blast	174,700	1.28
Total heat absorbed by blast..	9,770,000	71.53
Loss to dry stack gases.....	1,691,000	12.40
Loss to incomplete combustion	210,500	1.54
Loss to moisture in fuel gas..	27,520	.20
Loss to moisture in air for comb.	11,380	.08
Loss of heat to moisture from burning H_2	34,050	.25
Loss to radiation and unaccounted for	*1,911,000	14.00

*Includes heat lost by air leaks from stove and heat contained in air when pressure is relieved.

This heat balance shows nearly 2,000,000 B.t.u. in the "Radiation and Unaccounted For" item. Calculations based on the rate of heat transmission through the walls and the average temperature indicate that most of this item is Radiation Loss, and that a saving of approximately 1,000,000 B.t.u. per hour is easily accomplished by means of insulation.

A highly desirable effect of insulating a stove is that the mean temperature of the wall is increased, with the result that the amount of heat stored and the capacity of the stove are increased. An insulated stove consuming a given amount of fuel will produce a higher blast temperature than will be produced by an uninsulated stove burning the same amount, all other conditions being the same. This higher blast temperature may be made to result in a direct saving of coke in the blast furnace charge. On the other hand, if a higher blast temperature is not desired, less fuel need be burned in an insulated stove than in one without insulation to produce a given blast temperature.

Blast furnace gas is no less valuable per million B.t.u. **available** than other fuel which may be used for power generating purposes. Furthermore, since gas can be burned more efficiently than coal, a greater proportion of its heat content is available for useful work; and since it can be handled more cheaply than coal, a given heat content in the gas is more valuable than the same heat content in coal. Therefore, the less the amount of gas required by the stoves the more there is available for power requirements, with the result that there is an equivalent saving in other fuel.

After the blast has been heated to the desired temperature, it is highly desirable that it be delivered to the tuyeres with as little loss in temperature as possible; therefore, it is essential that the hot blast mains and bustle pipes be insulated to prevent excessive loss in temperature. The losses from these lines tend to defeat the purpose for which the blast was heated, and for that reason such losses should be kept as low as possible.

Heating Furnaces

The heat losses by radiation from heating furnaces constitute a relatively large proportion of the total heat supplied. This fact is very clearly brought out in the paper entitled "Heating Furnaces for Blooms, Slabs and Billets," by W. P. Chandler, Jr., Year Book of American Iron & Steel Inst., 1922. The heat balance shown in Table II is from Mr. Chandler's paper, and illustrates the extent of radiation losses.

Table II—Heat Balance of Heating Furnace

	B.t.u. per hr.	Per cent
Heat delivered	28,976,000	100.00
Heat absorbed by steel	18,017,000	62.18
Loss of heat in cooling water.	330,000	1.14
Loss to moisture burning H_2 ..	765,000	2.64
Loss to dry stack gases	5,088,000	17.56
Loss to radiation	4,775,000	16.48

While it is true that the radiation item includes radiation through furnace openings and unaccounted for losses, it is certain that very considerable savings may be effected through the use of insulation. In this connection it is of interest to note that to be a paying proposition, it is not necessary for the savings by insulation to be a large percentage of the total heat used. For example, in the case illustrated in Table II, one per cent of the total heat supplied is 289,760 B.t.u. per hour, which at a cost of heat of only 20c per 1,000,000 would amount to more than $500 per year. Even this small saving would pay a satisfactory return on a moderate amount of insulation, and a saving of 5% would pay a handsome return on the cost of highly effective insulation. In considering the savings due to insulation it must be borne in mind that in addition to the saving in the amount of heat conducted through the wall, insulation greatly reduces the losses due to air leakage through walls, and direct radiation through cracks in the walls.

With further reference to the fact that a saving by insulation representing a small percentage of the total heat supplied is no criterion as to whether or not insulation is a paying proposition, a familiar example may bring this out more clearly. A 10" steam line carrying steam at 200 lbs. pressure at a velocity of 5,000 ft. per minute, will deliver 79,500 lbs. of steam per hour. If this line is 1,000 feet long, and exposed to air at 70° F., the condensation due to heat loss would amount to about 3,600 lbs. per hour, or about 4.5% of the total flow. Yet this seemingly small percentage loss would, at 30c per 1,000 lbs. of steam, amount to over $9,000 per year. No one would consider leaving this line bare when, by the use of insulation the saving would amount to several times the cost of the insulation in one year. Nor would he consider leaving 100 feet of the line bare just because the percentage loss was only 0.45%, when he could save several dollars per year for each dollar invested. The true criterion, therefore, is the saving per year as compared with the cost per year of effecting that saving. This principle applies to furnaces as well as to steam pipes, even though the savings per unit of cost may not always be as striking as in the above example, nor do they need to be in order for insulation to be a paying proposition.

By-Product Coke Ovens and Regenerators

By-product coke ovens, because of the high temperatures maintained and their exposure to the weather, require efficient insulation. The losses from the tops in particular are excessive if not insulated. A further advantage of insulating the tops is that this results in a considerable lowering of the temperatures above

the ovens and in materially improved working conditions on top of the battery.

Insulation of the doors and door jambs results in greatly decreased heat loss, with the consequent saving in fuel. A further highly important advantage is that decreasing the heat loss assists greatly in maintaining the desired temperature at the ends of the oven. Therefore, increased attention is being given to insulation at these points.

In the case of coke oven regenerators, insulation not only reduces the heat losses due to conduction through the walls, but it also tends to minimize air leakage, which is a large factor in regenerator losses. Therefore, highly profitable savings may be effected by insulating such walls. This is true, not only for coke oven regenerator walls, but for walls of many other types of regenerators as well.

Conclusion:

In conclusion it may be said that the advantages of insulation are not confined alone to the saving of valuable heat. In many cases the improved working conditions, due to lower air temperatures near the heated equipment, is a very important consideration. But there is another outstanding advantage which in many cases outweighs all the others, even including the value of the heat saved. This advantage is that insulation, by maintaining the desired temperatures more uniformly, frequently results in considerably increased production from a given equipment. This means decreased labor cost and overhead, as well as decreased cost of heat per unit of product. Therefore, while it is not usually possible to evaluate some of these advantages in dollars and cents, nevertheless they should not be overlooked when considering the desirability of insulation.

Insulating materials are now available to meet the many and varied requirements in the industry, and it is certain that the use of insulation may profitably be extended to many types of equipment which are not generally insulated at the present time. The best evidence as to this increased field of usefulness of insulation is the fact that insulation is now used with such desirable results in so many places where a few years ago it was either considered unnecessary or suitable materials were not available.

DISCUSSION

George Naismith*: I would like to ask what would be the thickness of insulator required in furnace wall 22½" thick with steel plate, at a temperature of 2200° F.

A. W. Steed†: We are already convinced of the advisability of heat insulation wherever it is practical to apply same.

The question of painting bare surfaces and insulated surfaces should be of interest to everyone thinking along heat insulating lines.

Experiments on radiator elements for steam heat with reference to painting of the surface should be of interest to the gentlemen present.

Taking plain cast iron as having 100% radiating efficiency, the following paints have values for heat transmission as shown:

	Effc. of Surface as a radiator
Plain cast iron	100%
Copper bronze	76%
Aluminum bronze	72%
Enamel, terra cotta	103%
Enamel, gray	96%
Enamel, white	101%
Enamel, green glossy	99%
Enamel, green flat	96%
Varnish, brown	97%
Paint, white	98%
Paint, terra cotta	100%
Paint, light green	99%

The above table shows that the radiating efficiency of various paints varies to a marked degree.

It follows that a decided insulating effect can be had by painting with the bronze paints, especially on bare surfaces; and to a smaller degree on insulated surfaces.

W. P. Chandler*: In connection with heat loss from hot surfaces, I would like to ask what kind of surface that was, and whether different types of surfaces don't have different heat losses?

Dr. J. B. Unger†: While I am in accord with the statements made by Mr. McMillan in general, there is no doubt but what insulation has its place, I wish to speak in particular reference to insulation on blast furnaces and blast furnace stoves. Those of you who are familiar with that form of construction know that in building a blast furnace we allow a packing strip which we sometimes fill with a mixture of loam and crushed slag. In a stove we do the same thing. In blowing out a furnace and in taking out a lining we find an air space there. The function of the packing strip was to give us a soft, porous material in order that the brickwork as heated up was given an opportunity to expand. In the stove the condition is a trifle different. The stove will go through a hot period of approximately 4 hours, in which the brickwork will be expanded, and a cooling period of approximately one hour in which it will shrink. The average life of a stove is ten years. At the expiration of the life you find an air space. The packing material which was supposed to have a double purpose of giving a space in which brickwork might move and also act as an insulation, has failed; the air space alone has functioned. As a matter of fact, some builders of hot blast stoves are leaving nothing but air space and extending an occasional brick to act as a support, depending on air alone to act as an insulator. As to efficiency of air space, I think most of you are familiar with the work done by the U. S. government in Pittsburgh, in which they showed that air space was rather a poor insulator. If any insulation is to be applied to blast furnace or stove, to be really and truly efficient or to stay where it is put, it must be put on the outside of the steel shell. It cannot be put between the interior brickwork and steel shell because it isn't going to stay there very long. I saw a furnace blown out at one time in which a very expensive form of insulation had been put in between the brickwork and shell. At the end of the campaign the insulation

*Engineer, Heppenstall Forge & Knife Co., Pittsburgh, Pa.
†Steam Engr., American Rolling Mills, Middletown, Ohio.

*Special Engr., Carnegie Steel Co., Pittsburgh, Pa.
†Advisory Engr., Carnegie Steel Co., Pittsburgh, Pa.

was not in existence, although it was claimed at the beginning that this insulation would serve the furnace a second time, but it was a mass of dust and had settled to the bottom of the furnace.

I am simply pointing that out to bring out the fact that insulation, if applied at all to blast furnaces or stoves, should be on the outside. That necessarily makes it difficult to repair in case there is a leak at a seam, which sometimes occurs.

In respect to insulating an open hearth furnace, I am afraid it would be foolish to attempt to insulate the roof, the hot walls, or any part above the floor level. The temperatures required in the operation of an open hearth are so high that the brick used today will not stand any great length of time if well insulated. Silica brick, which makes up the bulk of the brickwork above the floor, is a very good conductor of heat, and if you insulate these bricks, confining that heat, you can imagine what will happen when you know a bulkhead wall will be destroyed in a matter of about 10 days, a roof in approximately 4 months, and a back wall in 5 or 6 weeks. If you confine heat by means of insulation at these points, the probability is you would reduce the life of the brick in those places to about one-fourth of that time. I have confined my remarks to hot blast stove, blast furnaces and the open hearth; not to insulation in other furnaces, in which temperatures much lower are used.

A soaking pit necessarily is under ground which makes it liable at times to damage by ingots, and unless the insulation is of an extremely rugged character it would not stand that abuse. Brick necessarily would have to be used for insulation of that character. Unless such bricks were as strong as the bricks of the furnace, I doubt if the insulation of a soaking pit is desirable.

In the matter of joints or flanges, pipes, tubes, or similar materials of that kind, I am thoroughly in accord with what Mr. McMillan has said.

Eugene Dowling*: Perhaps one of the leading accomplishments of a paper of this kind is that it encourages more interest in the particular subject than may have existed in the past. Most engineers make a conscientious effort to properly insulate various equipment, but frequently the other problems in plant design and construction keep them so busy that the subject of insulation does not receive the attention which they would otherwise give it. The result of this is that sometimes the insulation is not as effective as it should be, which fact is illustrated by cases which have been referred to by Dr. Unger.

In selecting the type of insulation to be used and the economical thickness, there are a number of important factors which must be considered. Frequently, great stress is laid on only one or possibly two of the desirable characteristics required, with the result that the material selected may be lacking in other essential qualities. Perhaps the most important factors to be considered are the following:

1. Thermal efficiency, low rate of heat transfer. The temperature conditions and degree of exposure must be considered in determining the thickness of material required to give desired insulating value. Where surfaces are exposed to wind and weather conditions, the use of additional thicknesses is desirable.

2. Heat resisting qualities. This item is very essential, but requirements exacted should not greatly exceed actual service conditions; because extremely high heat resistance can be obtained only by sacrificing some insulating value.

3. Permanence and durability. Materials must be suited to withstand operating conditions without serious deterioration.

4. Rigidity or elasticity. For some conditions a hard, rigid material is desirable, while on others a resilient material should be used.

5. Ease of application. This item may have considerable bearing on the labor cost of application.

6. Salvage value. In cases where steam lines may possibly be changed some time in the future, and where insulated furnaces may be rebuilt, the selection of a material which will permit of salvage and re-application is important.

7. Construction. Proper construction may be the most important item of all. Open cracks, seams and joints are avenues for the leakage of heat, and the construction should be such as to eliminate these effects. The use of insulation in large sheets tends to reduce greatly the number of joints, and where insulation may be applied in two or more layers, each succeeding layer should be applied so as to break or cover the joints in the preceding layer. This broken joint construction is especially important in the case of superheated steam lines.

Dr. Unger has brought out a number of points which are certainly worthy of very careful consideration. There is no question but that the insulation of the lower and hotter portions of a blast furnace should not be considered. The same is true of open hearth furnaces or any others where such extremely high temperatures are encountered. However, some of the other points raised by Dr. Unger might be somewhat misleading without further explanation. It is true that many stoves have been insulated with certain materials, and after a few years, examination has proven that the material has disappeared. On the other hand, there are a great many stoves throughout the country which have been insulated with more durable materials, and these stoves today, after several years of service, have insulation which is still intact. I have had an opportunity of making personal observations of a few stoves which have been torn down after a number of years of service, with the result that the insulation was found to be in excellent condition. This is a typical illustration of the value of using insulating materials which are adapted to the conditions involved.

There are a number of other insulation problems around a steel plant which are the reverse of those which have been discussed, in the sense that the function of the insulation is to keep heat away from where it is not wanted. An example of one of these was in a by-product coke oven plant where the engineers were concerned about the increase in temperature of the gas in the fuel gas line. This line ran along the regenerator chamber wall, and the radiation of heat from the wall was such as to heat up the line and cause a considerable increase in the gas temperature at the far end of the line. I do not know the exact figures, but the temperature at

*Engr., Johns-Manville, Inc., Cleveland, Ohio.

one end was about 80° F., and at the other end was something like 120° F. In order to permit of more accurate regulation of the ovens, and to prevent variations in the amounts of gas supplied to the different ovens due to fluctuations in relative temperatures at various points, the line was insulated, with the result that a practically constant gas temperature was maintained from one end of the line to the other.

A. G. Witting*: Eight years ago, when we built our last blast furnaces, we placed insulation in the hot blast stoves, which are two-pass. The insulation was placed over the dome, where the temperature probably is the highest, and is still in a perfectly good condition. As all the stoves of our later design were insulated, we have no comparative figures to tell the value of insulation, but the new stoves have a better heat economy than the old ones, and whenever one of these is rebuilt we install insulation both at the top and the bottom.

In connection with the question of insulating open hearth furnaces, I was reminded of a paper that a gentleman read before the British Iron and Steel Institute a couple of years ago. It described a new type of open hearth furnace, and in it was a statement that the roof had been insulated, with the result that it lasted longer. Has anybody heard anything more about this remarkable furnace?

With regard to the insulation of walls, particularly boiler walls, I would like to know if there is any formula giving the direct relation between the increase in temperature of the inside part of the brick work and the insulation. There are three distinctly different principles employed in the construction of boiler walls. The one is to prevent dissipation of heat by insulation; the second one is to absorb the heat given off to the wall in a screen of water piping; the third one is to place hollow tile in the wall and circulate air through it—the air thus heated being used for burning the fuel. In both the latter two instances heat has been removed from the brick wall, which thereby has been cooled off and the withdrawn heat has been usefully applied to the boiler. In the first instance, the brick walls will undoubtedly be hotter and act as a storage for heat, balancing to some extent any variations in the operation. It would be interesting to hear some comparison between the life of the brick work under the different conditions.

P. Nicholls†: As I have not been in touch with insulation as applied to steel works furnaces, I am rather loathe to enter into the discussion. I do think, however, that the turn of the discussion which was introduced by Dr. Unger, is along the correct lines, since there comes a point of demarcation and we have to talk in a different language when discussing insulation for refractory temperatures. You cannot consider insulation for refractory conditions unless you consider their reaction on the refractories. The two are bound up together. If you desire to save the large amount of heat which is lost through the outside of the furnace there are two options: (1) To prevent the heat loss by using insulation, which would seem to be a legitimate method provided the refractories have a refractoriness sufficiently high above the temperature of the furnace so that their life will not be shortened; (2) To utilize the heat which passes through the walls, although this would porbably be a more difficult matter than is the air cooling of boiler walls, in which the construction is more stable, repairs more easily made, and temperature not as varied as in steel furnaces. Personally, I would imagine that any very high temperature furnace, such as the open hearth in which you work to the limit of the brick work, that it would be advisable to attempt to save the heat by utilizing it rather than by preventing its dissipation. The addition of insulation to the outside of the wall will decrease the temperature gradient through the refractory, whereas cooling will have the opposite effect. Refractory investigations have not settled as to how the slope of the temperature gradient through the wall influences the tendency to spall, but apparently this is not definite enough to be of great importance. I do not know how practical it would be to attempt to utilize the heat to raise the temperature of air or water. Naturally such a proposal would have many objections.

The suggestion was made that you might paint your brickwork with aluminum paint. The advantage of such a coating to reduce the amount of radiation is not a myth, and it has been proved that surfaces so painted only radiate 70 per cent of the heat losses from the untreated surface, and the saving would increase as the temperature of the surface increases. As far as it might be of interest to save such an amount of heat, and as far as it were practical to so paint the surface, it would at least be worth trying.

L. B. McMillan: Referring to Mr. Naismith's question as to the thickness of insulation to be used on a furnace wall 22½" thick at a temperature of 2200° F., it is not possible to make a general recommendation which would apply to all cases. About 4" thick insulation would be in line with the average practice for such a condition. However, the economical thickness of insulation is dependent largely upon the value of the heat saved. In the case of electrically heated furnaces it would pay to use much thicker insulation, while, on the other hand, if the cost of heat were low, a lesser thickness of insulation would be sufficient. The temperature of 2200° F. is not so high as to bring the question of the limitations of refractories as to temperature into the problem; therefore, in this case the controlling consideration is that each increment of insulation must effect a saving which pays a satisfactory return on its cost.

Mr. Steed is entirely correct in his observations that the heat dissipated by a radiator or bare steam pipe with a rusty surface will be much greater than when the surface is painted with aluminum paint. The surface resistance of a bright metallic surface is much greater than for a dull or oxidized surface. In the case of a radiator or bare steam pipe practically all of the resistance to heat flow is at the outer surface; therefore, any change in surface resistance produces a corresponding change in total heat loss. The rate of heat loss is the reciprocal

*Assistant Chief Engr., Illinois Steel Co., Gary, Ind.
†Fuel Engr., U. S. Bureau of Mines, Pittsburgh, Pa.

of the total resistance. Doubling the total resistance would cut the heat loss in half. Using Mr. Steed's figures, a decrease in heat loss to .7 of the original value would correspond to an increase in total resistance of $\frac{1}{.7} = 1.43$ times the original resistance, or an increase in resistance of 43 per cent. But, on the other hand, in the case of furnace walls and insulated surfaces, the surface resistance is only a small fraction of the total resistance. For example, in the case shown on page 304, where the total resistance is 5.80 and the surface resistance is .42, the latter is only 7.2 per cent of the total. Increasing the surface resistance 43 per cent would increase the total resistance to 5.98, and would result in a decrease in heat loss of only 3 per cent, as compared with the decrease of 30 per cent in the case of the bare surface.

In reply to Mr. Chandler's question, the charts in the paper are based on losses from oxidized metal surfaces. However, for brick surfaces the values are very nearly the same. Some of the tests referred to in the paper as showing greater increases due to air velocity than indicated by the charts, were on brick surfaces, but also some were on dull metal surfaces. There is, of course, a very considerable difference in surface resistance in the case of a bright polished surface as compared with a dull surface.

Dr. Unger is absolutely right that there are places where insulation should not be used. In the paper it was mentioned that open hearth furnaces and blast furnaces were places where insulation was not as yet a good thing. Soaking pits may also be added to the list, because of the effect of extremely high temperatures on available refractories. However, insulation of hot blast stoves is not to be condemned because certain materials used in the past have not proven satisfactory. Materials are available which will stand up satisfactorily when applied between the brick work and the steel shell. Mr. Witting's discussion gives conclusive evidence on this point. Placing the insulation inside the steel shell is much to be preferred to placing it on the outside, as suggested by Dr. Unger, because the latter method would increase the temperature of the steel shell and might cause it to be subjected to excessive temperatures.

Referring to Mr. Witting's question regarding turbine insulation, two types of insulation have been used for this purpose. The type most generally used consists of molded block insulation applied in two layers broken joint construction, with asbestos cement finish. Recently blanket type insulation has been used to some extent. This consists of asbestos fibre quilted between layers of asbestos cloth. In either case a metal casing is used to provide the exterior finish.

The temperature at any point in a wall may be estimated approximately on the basis that the temperature drop through any element of the construction bears the same ratio to the total temperature drop as the resistance of that element of the construction bears to the total resistance. This method would give a fairly close approximation were it not for the fact that, as pointed out in the paper, heat is conducted along the wall itself, from the portions subjected to the highest temperatures to the cooler parts of the wall. Therefore, the actual temperatures to which the refractories are subjected will usually be lower than the calculated values. This has been borne out by a great many actual tests on furnace walls.

Insulation has been used successfully for many years on boiler walls of the ordinary type. The constructions with water screens and those with ventilated walls, to which Mr. Witting referred, have been developed to take care of the extremely severe conditions resulting from the use of larger boiler furnaces operated at very high overload capacities, particularly in connection with the use of pulverized coal. Both types are usually insulated. In the case of the water screen type the insulation is usually placed on the outside of the wall, and in the ventilated type the insulation and a steel casing are placed outside of the space through which air for combustion is circulated and preheated.

Referring to Mr. Nichols' remarks regarding the limitations of refractories, it is true, as pointed out in the paper and in reply to Dr. Unger's discussion, that there are cases, such as the hotter portions of blast furnaces, open hearth furnaces and soaking pits, where insulation should not be recommended in connection with refractories now available. However, there are so many furnaces operating at temperatures well within the range of available refractories that, leaving the others out of consideration, there are a great many places in industry where insulation may be used with highly economical results.

Iron and Steel Exposition

Philadelphia Commercial Museum, Philadelphia, Pa. September 14-19, 1925

For Space Write

Iron and Steel Exposition

706 Empire Bldg. Pgh, Pa.

Iron and Steel Exposition
September 14th to 19th, 1925

Philadelphia Commercial Museum

120,000 Square Feet

For Reservations Write
Iron and Steel Exposition, Empire Bldg., Pittsburgh, Pa.

Manufacturers Who Will Exhibit At the Iron and Steel Exposition

Square D Company
Norma Company of America
Robinson Ventilating Co.
Fuller Lehigh Company
Baker R & L. Company
Trumbull Electric Mfg. Co.
Pittsburgh Transformer Co.
Rowan Controller Co.
Morgan Engineering Co.
Cutler Hammer Mfg. Co.
Bartlett Hayward Company
Hyatt Roller Bearing Co.
Edison Storage Battery Co.
Standard Underground Cable Co.
Benjamin Elec. Mfg. Co.
Calebaugh Self Lubricating Carbon Co.
Roller Smith Co.
Electric Storage Battery Co.
Monitor Controller Co.
Allen Bradley Co.
Republic Flow Meters Co.
Tinius Olsen Testing Machine Co.
American Pressed Steel Co.
Thomas Flexible Coupling Co.
Detrick Arch Co.
Sharples Specialty Co.
Cutter Elec. & Mfg. Co.
Allis Chalmers Mfg. Co.
Craven Electric Sales Co.
Alliance Machine Co.
SKF Industries, Inc.
Crouse Hinds Company
Ohio Electric & Controller Co.
Bussman Mfg. Co.
National Carbon Co.
National Elec. Mfg. Co.
Erie Malleable Iron Co.
Pyle National Co.
Electric Service Supplies Co.
Electric Controller & Mfg. Co.
Martindale Electric Co.
Mutual Elec. & Machine Co.
Rollway Bearings Co.
V. V. Fittings Co.
Keystone Lubricating Co.
United States Graphite Co.
The Bristol Company
Chicago Fuse Mfg. Co.
Corliss Carbon Co.
Thompson Electric Co.
Stackpole Carbon Co.
Otis Elevator Company
Johns Manville, Inc.
General Electric Co.
Economy Fuse & Mfg. Co.
Westinghouse Elec. & Mfg. Co.
Condit Elec. Mfg. Co.
Reliance Elec. & Engineering Co.
Philadelphia Grease & Mfg. Co.
Appleton Electric Co.
McGraw Hill Company
Nichols Lintern Company
Tool Steel Gear & Pinion Co.
Heppenstall Forge & Knife Co.
American Electric Fusion Corp.
Electric Journal
Packard Electric Co.
Homestead Valve Mfg. Co.
John C. Dolph Co.
Mutual Foundry & Machine Co.
Gehnrich Indirect Heat Oven Co.

Items of Interest

The Cleveland Electric Tramrail Company announces the following changes:

Mr. G. W. Eichhoff, formerly District Manager in charge of the Chicago office, has been appointed Sales Specialist in charge of Tramrail sales in the Ceramic and Paper Industries. Likewise, Mr. H. T. Florence, Specialist in the Rubber Industry.

The following companies were recently appointed Tramrail dealers in their respective territories:

The Kirkby Machinery Co., 109-111 St. Clair St., Toledo, Ohio.

J. H. Overpeck Company, House Building, Pittsburgh, Pa.

A. D. Heath Machinery Co., Merchants Bank Bldg., Indianapolis, Ind.

Julius Andrae & Sons, Broadway and Michigan Sts., Milwaukee, Wis.

Mr. Geo. E. Coursey, 701 Union Central Bldg., Cincinnati, Ohio.

D. H. Braymer Equipment Co., 727 W. D. W. Building, Omaha, Neb.

The Chicago Fuse Mfg. Co., of Chicago, manufacturers of Union and Gem Fuses and Union Outlet and Gem Switch Boxes, have moved their Philadelphia office from the Weightman Building to 517 Packard Building.

The General Electric Company has issued a booklet which is profusely illustrated with photographs, diagrams, tables, formulas, covering the installation, operation and maintenance of switchboards. This booklet is known as Number 87000-E.

The Chicago District Section held an outing at the Oak Hills Golf Club, Tuesday, July 14th, which is claimed was the greatest golf event of the century. Many prizes were awarded.

The American Heat Economy Bureau, Wabash Bldg., Pittsburgh, Pa., announces the following contracts for Steinbart Pressure Burners and the Huessener Combustion Control:

Donner Steel Co., Buffalo, N. Y., 6 boilers.
Central Furnace Co., Massillon, O., 5 boilers.
Central Furnace Co., Massillon, O., 4 stoves.
Carnegie Steel Co., New Castle, Pa., 6 boilers.
Illinois Steel Company, Gary, Ind., 8 boilers.
Bourne Fuller Co., Cleveland, O., 5 boilers.
By-Product Coke Corp., Chicago, Ill., 4 stoves.
Mystic Iron Works, Boston, Mass., 3 stoves.
Mystic Iron Works, Boston, Mass., 3 boilers.
Trumbull Steel Company, Warren, O., 3 open hearth furnaces.
Donner Steel Company, Buffalo, N. Y., 1 open hearth furnace.
Otis Steel Company, Cleveland, O., 1 open hearth furnace.
Bethlehem Steel Co., Johnstown, Pa., 5 billet furnaces.
Bethlehem Steel Co., Lackawanna, N. Y., 2 billet furnaces.
Frodingham Iron & Steel Co., Consett, England, 2 stoves.
Frodingham Iron & Steel Co., Consett, England, 1 soaking pit.

The total equipment of Steinbart Pressure Burners and Huessener Combustion Control disposed of during the last few years exceeds $1,000,000.

The announcement is also made of the opening of a branch office, under the name of The International Heat Economy Bureau, Ltd., at the Brook House, Walbrook, London, England. Mr. John Miles, who was formerly connected with the Freyn and Brassert Co., Chicago, Ill., will be in charge of the London branch.

The Philadelphia Section announces the election of officers for the ensuing season:

Chairman H. S. Boone, Elec. Engr., Shoemaker Bridge Co., Pottstown, Pa.; vice chairman, Fred O. Schnure, Elec. Engr., Bethlehem Steel Co., Sparrows Point, Md.

Executive Committee—J. G. Walz, Asst. Elec. Supt., Bethtlehem Steel Co., Steelton, Pa.; George Pfeffer, Elec. Supt., Florence Pipe Foundry and Nut Co., Florence, N. J.; P. T. Vanderwaart, past chairman, Elec. Supt., New Jersey Zinc Co., Palmerton, Pa.

The Philadelphia District Section entertained the Engineers of the Philadelphia District at an outing on June 13th, which was enjoyed by everyone present. A three-act farce comedy was produced under the personal direction of Linn O. Morrow. The show was a howling success.

The Birmingham Section of the Association of Iron and Steel Electrical Engineers, together with the Alabama Technical Society, entertained the engineers of the Birmingham District with a trip to Muscle Shoals. The committee in charge were: F. G. Cutler, W. H. Gilbert, W. V. Dunn, A. F. Elliott. Everybody reports having a good time.

A 60-inch dial power indicator, visible at a distance of 250 feet, has been designed by the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa. It is used advantageously in boiler rooms, for indicating the total load of a power station. This giant relay-type indicator greatly facilitates the work of the boiler room operators, saving considerable time, labor and inconvenience.

In this large relay-type indicator the pointer is driven by a small motor, which is energized through the contacts of the measuring element.

The cases are constructed of sheet steel and angle iron riveted together, and are so designed as to be dust tight, all doors having felt packing. The windows in the cases are of plate glass supported in a cushion mounting. The dials are black with white figures and are illuminated by lamps concealed in the case. Doors in the case permit easy access for replacement of lamps and lubrication of moving parts when required.

The case of this dial indicator is about 72 inches square and 30 inches deep and can be supplied with either a single or double face.

This indicator may be furnished with a polyphase watt-meter element to operate from the totalizing current transformers or with a direct current ammeter element to operate from a remote metering apparatus.

A unique application of an electric hot-plate for lowering the temper of the working ends of an open header dies and solid cold-foroging tools is made at the plant of the Buffalo Bolt Company, North Tonawanda, N. Y., manufacturers of bolts, wire and bar material. At this plant many tools and dies are made which must be specially heat treated in order to obtain production output on automatic and semi-automatic machines. In the case of header dies and solid cold-forging tools, it is essential that the body of the tool be of unusual hardness, it being necessary at the same time, that the working ends themselves have less of the characteristic of hardness and more that of toughness.

The dies and tools are first heated to a temperature of 1450 to 1500° F. in an electric furnace and then quenched in a saline solution. After cooling they are again heated, this time in an electrically heated oil tempering bath to a temperature of approximately 450° F. They are then allowed to cool to normal air temperature. Ordinarily, this cycle would constitute the complete heat treating process.

The tools and dies in question, however, are subject to great strains and shocks. In the case of carriage bolt open header dies, particularly, the square neck opening with its sharp corners constitutes a weak working part and, unless sufficient toughness is imparted to the metal at this point, the life of the die will be short.

Accordingly, in order to provide the proper element of toughness at the point where it is needed, without destroying the great hardness in the body of the dies and tools themselves, the Buffalo Bolt Company has installed an electric hot-plate, manufactured by the General Electric Company, for tempering the ends. The dimensions of the plate are approximately 9x18 inches and the electric heating element, suitably insulated, is cast in the plate itself, providing a suitably insulated, is cast in the plate itself, providing a suitably strong construction for withstanding the severe service imposed. The plate rests on a small, electrically welded frame about two feet in height.

After cooling from the oil tempering treatment, the working ends of the dies and tools are polished with emery cloth. They are then placed on the heated plate and left there until the ends assume bluish color, indicating that the drawback operation has been completed. They are then removed and allowed to cool in the open air. The hardness of the working ends is thus reduced to give greater toughness and less brittleness, the original hardness of the tool and die body remaining. The operation is quickly performed and has been found to increase materially the life of the dies and tools in question.

The plate has been found to be simple and inexpensive, clean and safe, giving off no smoke, soot or fumes. The plate, oil tempering bath and electric furnace used in the operations described are all General Electric products.

A new type of switchboard, constructed of "stretcher level sheet steel," has been designed by the Westinghouse Electric and Manufacturing Company, that may be used advantageously in Power, Railway Industrial and Marine installations. This new type of switchboard is light, substantial, sturdy and easily erected.

The influx of steel switchboards has been a gradual one since 1915, when it was found that the ordinary slate and marble boards would not stand up under severe operating conditions. They were brittle and easily broken and were subject to stain by oil, which marred the appearance of the board. In addition they were heavy and cumbersome.

For some time stretcher level steel switchboards have been used on small installations in a more or less experimental way and have proved successful, so that they are now being installed on larger projects. The outstanding features of this new type are its lightness, substantial nature, appearance and expensiveness. The erection and maintenance costs are lower than those of the slate and marble boards. The erection, in addition to being cheaper, is more simple, since the framework is an integral part of the panels.

The steel panels are given a baked enamel finish ismilar to that used in the auto industry. They thus present a most pleasing appearance and, in addition, are impervious to moisture and easily resist the corroding action of salt sea air.

The most important installations from the power and railway standpoint are those of the Staten Island project, which is part of the complete electrification of the B. & O. system from Baltimore to New York, and the installation in the automatic substations of the Steubenville, East Liverpool and Beaver Valley Traction Company.

The following contracts were awarded to the Westinghouse Company:

By the Carnegie Steel Company, Homestead Works: For 2 1500 kw., 500 rpm., synchronous motor generators, 6600 volts, 3 phase, 25 cycle. These sets will be supplied with automatic switching equipment and will be used in connection with the new development at the Homestead Works.

By the Inland Steel Company, Indiana Harbor, Ind.: For 1 7000 hp., 50/120 rpm., 700 volt, d.c, reversing motor, with flywheel motor generator set, switchboard and control. This equipment will drive a 36" reversing rougher.

By the Wisconsin Steel Company, Chicago, Ill.: Drive for No. 5 merchant mill, consisting of: 1 3100 hp., 70/150 rpm., 600 volts, d.c. reversing motor with flywheel motor generator set, exciter set, and control.

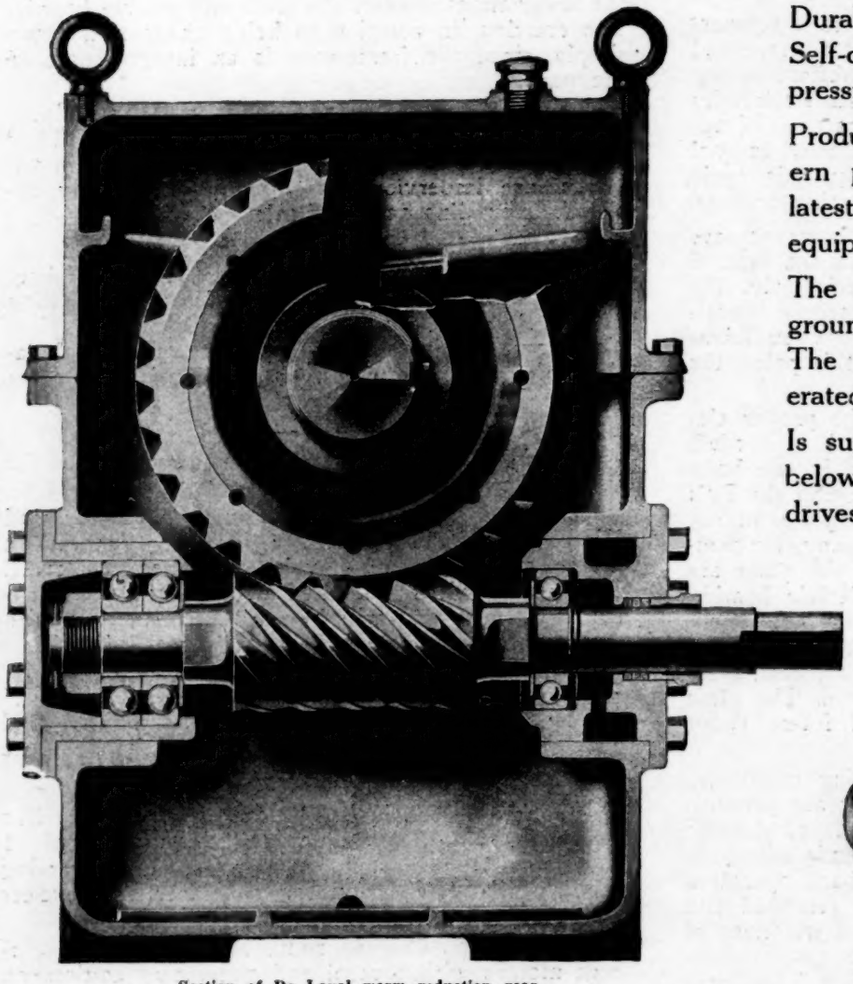
3—2000 hp., 230/460 rpm., 700 volts, direct current motors with control and generating equipment.

1—1000 kw., 720 rpm., 250 volts, synchronous motor generator, 2200 volts, 3 phase, 60 cycle.

Contracts were awarded to the Morgan Engineering Company by the Youngstown Sheet and Tube Company for 19 Heavy Duty Mill Type Cranes.

Contracts were awarded to the Reliance Electric and Engineering Company by the Bethlehem Steel Co. for 88 20 HP., 600-1800 R.P.M. motors for driving individual wire blocks. These motors are for use at the Sparrows Point plant and are duplicates of those installed at Johnstown. The Electric Controller and Manufacturing Company will furnish all the control in connection with this installation, at Sparrows Point.

De Laval
Worm Reduction Gear
A Superior Speed Reducer



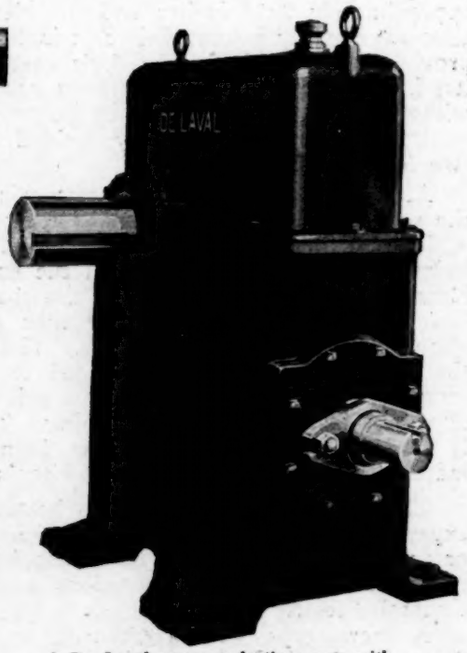
Section of De Laval worm reduction gear in the plane of the worm axis.

Durable, efficient and noiseless. Self-oiling, with low bearing pressures.

Produced to limit gages by modern precision methods and with latest development in mechanical equipment.

The hardened steel worm is ground to correct tooth contour. The bronze wheel rim is generated by special machines.

Is supplied with worm above or below wheel and for vertical shaft drives.



De Laval worm reduction gear with bottom drive worm.

De Laval
Steam Turbine Co., Trenton, N.J.

Local Offices: Atlanta, Boston, Charlotte, Chicago, Cleveland, Dallas, Denver, Duluth, Helena, Houston, Indianapolis, Kansas City, Los Angeles, Montreal, New Orleans, New York, Philadelphia, Pittsburgh, Portland, Ore., St. Paul, Salt Lake City, San Francisco, Seattle, Toronto, Vancouver. 410

Manufacturers of Steam Turbines, Centrifugal Pumps, Centrifugal Blowers and Compressors, Double Helical Speed Reducing Gears, Worm Gears, Hydraulic Turbines, Flexible Couplings and Special Centrifugal Machinery